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CATTARAUGUS CREEK HARBOR, NEW YORK GENERAL DESIGN MEMORANDUM. P--ETC(U)
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The purpose of this Phase 11 General Design Memorandum is to present the detailed design of the Cattaraugus Harbor improvements. This report describes the changes in the local cooperation requirements, costs, and benefits that have accrued due to changes in design and price levels since preparation of the Phase 1 General Design Memorandum.

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DEPARTMENT OF THE ARMY
BUFFALO DISTRICT, CORPS OF ENGINEERS
1776 NIAGARA STREET
BUFFALO, NEW YORK 14207

NCBED-DG 31 March 1976

SUBJECT: Cattaraugus Creek Harbor, NY Phase II GDM

THRU: Division Engineer, North Central
ATTN: NCDED

TO: Chief of Engineers
ATTN: HQDA (DAEN-CWE-B)

In accordance with ER 1110-2-1150, inclosed are 20 copies of the subject memorandum. Also inclosed are three copies for retention by the Division Engineer.

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BERNARD C. HUGHES
Colonel, Corps of Engineers
District Engineer

VANGUARD OF FREEDOM UNITED STATES ARMY

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

GENERAL DESIGN MEMORANDUM
FOR
CATTARAUGUS CREEK HARBOR, NY

PHASE II - PROJECT DESIGN

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

List of Tables

PLATES

TABLE OF CONTENTS (Cont'd)

APPENDICES

CATTARAUGUS CREEK HARBOR, NY

GENERAL DESIGN MEMORANDUM
PHASE II - PROJECT DESIGN

PERTINENT DATA

PROJECT FEATURES:

Two breakwaters

Walkway and handrail on south breakwater

Navigation lights (2)

One riprapped berm

Dredged navigation channel

DIMENSIONS:

South Breakwater

Length	1850 ft.
Height above LWD	+14 ft.
Side slope	1.5H to 1V
Crest width	15 ft.

North Breakwater

Length	600 ft.
Height above LWD	+10 ft.
Side slope	1.5H to 1V
Crest width	12 ft.

Berm

Length	550 ft.
Elevation above LWD	+11 ft.
Side slopes	2H to 1V
Crest width	6 ft.

PERTINENT DATA (Cont'd)

Channel

Length	5000 ft.
Creek	3500 ft.
Outer channel	1500 ft.
Project depth	
Creek (6 ft. of water during navigation season)	-3.5 ft. LWD
Outer channel (8 ft. of water during navigation season)	-5.5 ft. LWD
Width	
Creek	100 ft.
Outer channel	100 ft.
Entrance	200 ft.
Side slopes	2H to 1V

QUANTITIES:

South Breakwater

A6 ton armor stone	30,000 tons
A4 ton armor stone	8,400 tons
Al ton armor stone	1,400 tons
B.6 underlayer stone	5,300 tons
B.4 underlayer stone	1,200 tons
Cl core material	25,500 tons
Dl bedding	5,500 C.Y.
Filter cloth	3,000 S.F.
Concrete	3,300 C.Y.
Reinforcing bars	1,600 Lbs.

North Breakwater

A3 ton armor stone	8,700 tons
Al ton armor stone	700 tons
B.3 underlayer stone	1,500 tons
Cl core material	7,400 tons
Dl bedding	1,700 C.Y.
Filter cloth	2,000 S.F.

Berm

Al ton armor stone	6,000 tons
B.1 riprap	5,600 tons
Fl filter	4,100 tons

PERTINENT DATA (Cont'd)

Channel

Dredge	35,000 C.Y.
Spit removal (North and South)	36,900 C.Y.
R.5 riprap	7,500 tons
F2 filter stone	2,600 tons

ECONOMICS:

First Costs

Federal (C of E)	$3,093,500
Federal (U.S.C.G.)	20,000
Non-Federal	1,785,500
Total	$4,899,000

Annual Costs

Federal (C of E)	$ 194,800
Federal (U.S.C.G.)	2,700
Non-Federal	100,900
Total	$ 298,400

Benefits	$ 386,520
Benefit/Cost Ratio	1.30

Data

Vertical control

Low water datum = 568.6 feet above IGLD, Father Point, Quebec (1955)

Horizontal control

Survey Point A - 5000E, 5000N

Construction Schedule	Duration
Plans and specifications	4 months
Advertise and award construction contract	3 months
Construction	Two construction seasons

GENERAL DESIGN MEMORANDUM
FOR
CATTARAUGUS CREEK HARBOR, NEW YORK

PHASE II - PROJECT DESIGN

I - INTRODUCTION

1. The purpose of this Phase II General Design Memorandum is to present the detailed design of the Cattaraugus Harbor improvements. This report describes the changes in the local cooperation requirements, costs, and benefits that have accrued due to changes in design and price levels since preparation of the Phase I General Design Memorandum.

II - LOCAL COOPERATION

2. LOCAL COOPERATION REQUIREMENTS

Updated Local Cooperation in accordance with House Document No. 97, 90th Congress, 1st Session (Project Authorization) and as modified by project changes require that, prior to construction, local interests furnish assurances satisfactory to the Secretary of the Army that they will:

a. Contribute in cash 50 percent of that portion of the first cost of Federal construction allocated to navigation, such contribution presently estimated at $1,766,500 (September 1975 price levels) to be paid either in a lump sum prior to initiation of construction, or in a lump sum prior to initiation of construction, or in installments over the construction period at a rate proportionate to the proposed or scheduled appropriation of Federal funds, the final apportionment of cost to be made after actual costs have been determined;

b. Provide without cost to the United States all lands, easements, and rights-of-way required for construction and subsequent maintenance of the project and for 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 and any necessary retaining dikes, bulkheads, and embankments therefor, or the cost of such retaining works;

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

d. Establish a competent and properly constituted public body empowered to prescribe and enforce regulations pertaining to flood control and to regulate the use and development of the harbor and related facilities, with the understanding that said facilities will be open to all on equal terms;

e. Provide and maintain without cost to the United States: depths in the service channels to principal docks and berthing areas commensurate with those provided in the Federal project; and necessary mooring facilities and parking and service areas, including a launching ramp, sanitary facilities, and an adequate public landing ramp, sanitary facilities, and an adequate public landing or wharf, with provision for the sale of motor fuel, lubricants, and potable water, available to all on equal terms;

f. Contribute in cash 27 percent of the annual Federal maintenance costs, excluding aids to navigation, such contribution representing the costs allocated to flood control for channels and breakwaters, an amount presently estimated at $24,200 (September 1975 price levels) annually;

g. Prescribe and enforce regulations to prevent encroachment or obstruction on channels and rights-of-way necessary to proper functioning of the project for flood control;

h. Establish regulations prohibiting discharge of untreated sewage, garbage, and other pollutants in the waters of the harbor by users thereof, which regulations shall be in accordance with applicable laws or regulations of Federal, State, and local authorities responsible for pollution prevention and control; and

i. With respect to the recreational facilities:

(1) Pay, contribute in kind or repay (which may be through user fees) with interest, one-half of the cost of modifications necessary to provide for recreational fishing on the breakwater, and one-half of the cost of associated access facilities, parking areas, and sanitary facilities, the amount involved being currently estimated at $8,000 (September 1975 price levels), subject to final adjustment after actual costs have been determined; and

(2) Bear all costs of maintenance, operation, and replacement of the modifications and associated facilities, the amount involved being currently estimated at $1,600 (September 1975 price levels) on an average annual basis;

Provided that the improvement for navigation and flood control may be undertaken independently of providing public recreational facilities for breakwater fishing whenever the required local cooperation for navigation and flood control has been furnished.

3. CHANGES IN LOCAL COOPERATION REQUIREMENTS

The Project Document and Phase I General Design Memorandum assumed that the recreational fishing benefits would be taken from the breakwater on the north side of the creek. An access road, parking lot, and comfort station were proposed to be constructed on the Indian Reservation. The present breakwater alignment has the longer breakwater attached to the south side of the creek. Recreational fishing benefits are now to be taken from the longer breakwater on the south, as shown in Plate 1. A comfort station, access road, and parking facilities exist on the south shore. The Town Board of Hanover favored the modified plan in a meeting held on August 11, 1975, and agreed to make the existing restroom and parking facilities available to all on an equal basis. The percentage of the non-Federal annual maintenance cost contribution was reduced from the 34 percent in the phase I GDM to 27 percent because the costs allocated to flood control for channels was substantially reduced. This reduction was achieved by changing the project channel depths from -6 and -8 LWD to 6 and 8 feet of water respectively. Less annual excavation will be needed to maintain the channels with the new depths. Since the upstream levees were eliminated because of the change in project channel depth, locals are relieved of maintaining or operating any flood control portion of the project above the navigation channel.

III - LOCATION OF PROJECT AND TRIBUTARY AREA

4. The project improvements are to be constructed at the mouth of Cattaraugus Creek in Lake Erie, along the creek centerline and extending 1.0 mile upstream from the creek mouth. Cattaraugus Creek enters Lake Erie approximately 24 miles southwest of Buffalo and 12 miles northeast of Dunkirk, NY. The town of Hanover in Chautauqua County is on the southern side of the creek, and the town of Brant, Erie County, is on the northern side of the creek. The Cattaraugus Indian Reservation of the Seneca Nation, New York Indians, occupies the entire northern side of the creek within the study area. Most residential and boat owners reside in the Buffalo area. Recreational fishermen come from a large area, as far away as the Midwest as a result of State programs, which stock Coho and Chinook Salmon and Rainbow Trout. Flood control benefits are provided for Sunset Bay, and parts of the Cattaraugus Indian Reservation.

IV - HYDROLOGY

5. CLIMATOLOGY

The Cattaraugus Creek watershed covers an area of 554 square miles in western New York. Cattaraugus Creek is about 70 miles long and flows in a general westward direction to Lake Erie. The regional climate is temperate, humid-continental, and is characterized by rapidly changing weather. The prevailing winds at the project site are southwesterly from over Lake Erie. Strong winds are common throughout the year because of this exposure. The lake has a moderating influence on temperature in the lower areas of the watershed, with greater temperature extremes occurring in the hilly areas farther removed from the lake. Two climatological stations are located within the Cattaraugus Creek watershed, one at Gowanda State Hospital (Lat. $42^{o}29'$N and Long. $78^{o}56'$E) and the other at Arcade (Lat. $42^{o}32'$N and Long. $78^{o}25'$E). Stream flow data from the Gowanda gage were used in this study. The drainage area for the Gowanda gage is 428 square miles, as compared to the 554 square miles at the river mouth. Discharges for design floods were increased by a factor of 1.29 to account for the differences in watershed areas between the gage and river mouth. The monthly precipitation for the two climatological stations varies from a maximum of 4.04 inches in June to a minimum of 2.24 inches in February. The average annual precipitation computed from records of the two stations is 38.29 inches. The average annual snow fall recorded at the Arcade Station is 92.2 inches. The highest average monthly snowfall, which occurs during January, is 22.1 inches. The annual average temperature, based on the two stations, is 46.4 degrees Fahrenheit. July has the warmest average monthly temperature of 70.0^{o} at Gowanda, and January has the coldest average monthly temperature of 18.7^{o} at Arcade.

6. FLOODS OF RECORD

Damaging floods along Cattaraugus Creek have a reported history dating back 100 years. Because the resort areas near the mouth of the creek have developed primarily only during the last 30 years, good information on flood events prior to that time is not available. During the period of the Gowanda gage record, significant flooding occurred at the mouth of the creek in March 1942, June 1944, April 1947, February 1953, October 1955, March 1956, January 1957, January 1959, February 1961, March 1963, March 1972, June 1972 and as late as February 1976. Although each of the flood events was coincident with a high discharge in the creek, most of the higher stages were aggravated by ice jams near the mouth.

7. FLOOD-PRODUCING FACTORS

Sand bars frequently form across the mouth of the creek. In the late winter and early spring, lake ice is windrowed on shore by lake storms, increasing the barrier effect of the bars. These obstacles impede access to the lake of creek discharges and, therefore, affect water-level stages near the mouth. The effects of these obstructions are particularly apparent during the spring thaw when ice floes carried down the creek by the high discharges are blocked by the sand bar and lake ice at the creek mouth. During discharges developed by the combination of rainfall and snow melt, ice jams raise the water surface to significantly higher levels than would occur in an open channel.

This combination of discharge and ice-jamming of the creek caused the larger of the recorded flood events. The storms of October 1954, October 1955 and September 1967, although among the larger rainfall producers, caused only minimum damage at the mouth because unobstructed access to the lake was then available. Detailed investigation of the coincidence of intense rainfall with large runoff was not considered necessary to develop the design criteria because of this over-riding effect of ice jams and sand bars on the major recorded floods.

8. DESIGN DISCHARGE FOR IMPROVEMENTS

The improved channel section was designed for navigation criteria and has the same channel capacity as the present channel with the elimination of conditions which now cause sand bars and ice jams. The capacity of the present channel is 22,000 cfs. Damaging stages would be exceeded on the average of about once in three years. A higher level of flood protection could not be economically justified.

V - GEOLOGY, SOILS, AND SHORE PROCESSES

9. GEOLOGY AND SOILS

A subsurface exploration program was conducted at the project site in 1975 to determine foundation conditions and soils properties for application to design of the project features. The subsurface explorations included nine borings taken in the lake in the vicinity of the breakwaters and channel, 8 borings taken in the proposed dredged creek channel, 6 borings taken on land for the breakwaters and berm, and 7 borings taken for the fills. Eight test pits were opened to evaluate soil conditions at the berm and fills. One boring, D-75-24, was taken on the river bank at the site of a proposed channel riprap. The locations of the borings are given in Plate 1. The logs of subsurface explorations are given in Plates C2 through C5, and soils profiles are presented in Plate C1. A detailed description of the soils and foundation conditions is given in Appendix C, Geology, Soils, and Construction Materials.

10. The soils over which the breakwaters are to be constructed and the channels in the lake are to be dredged are alluvial and glacial deposits. The lake bottom comprises a 2- to 8-foot-thick layer of alluvial deposits of a loose-to-medium compact fine sand. Underlying the alluvial deposit is a 2- to 11-foot thick layer of glacial outwash, which comprises a medium-to-compact sand and gravel. A 4- to 20-foot thick layer of medium-to-compact glacial till underlies the glacial outwash. This till is sand and gravel, with varying amounts of silt and cobbles. Glacio-fluvial and glacial lake deposits underlie the glacial till. The glacio-fluvial deposits have a layer thickness of 15 to 40 feet and comprise a very stiff silt and very compact silty sand or fine sandy silt. The glacial lake deposits are medium-stiff-to-stiff varved silty clay and clayey silt.

11. The rubblemound breakwaters are compatible with the foundation conditions. However, a layer of bedding material is recommended to be placed over the loosely compacted fine sand. This layer will provide a filter bedding to prevent the movement of fines in the base material through the voids in the structure and thus to reduce settlement of the structure. The bedding should be a coarse sand to medium gravel, and material dredged from the riverbed, berm, or sand spit may be adequate for such use. Minor compression of the alluvial and glacial outwash sands will occur during breakwater construction and for a short time thereafter. Consolidation of 2 to 3 inches is anticipated.

12. Machine-excavated test pits along the berm centerline indicated a very loosely compacted sand and gravel. Material forming the spit on which the berm is to be placed have been deposited periodically by creek discharge and re-distributed by wave action. The spit changes configuration as a function of the creek discharge and wave action. The spit is, therefore, loosely compacted. The loose compaction renders the material relatively unstable, and a maximum slope steepness of 2 horizontal to 1 vertical is recommended for the berm design.

13. The bed of the creek channel is covered by a thin layer of silt and clay-size material. This alluvial deposit overlies a sandy gravel bed. The sandy gravel bed was derived from glacial outwash and alluvial deposition occurring during high-discharge floods in the recent past. The borings terminated within 10 feet of the creek bottom in sandy gravel. No bedrock was encountered. A maximum of 2.5 feet of material are to be removed by dredging and no dredging difficulties are anticipated in that operation. These materials are suitable for bedding layers or for beach nourishment.

14. The soils over which the fills are to be constructed comprise a thin stratum of topsoil overlying an 8- to 13-foot layer of loose sand and silt derived from alluvial deposits. A 2- to 10-foot stratum of loose-to-compact, coarse-to-fine sand derived from glacial outwash underlies the alluvial deposits. Glacial till and glacio-fluvial deposits underlies the glacial outwash. Six feet of weathered shale were encountered at Elevation 538.7 IGLD in the upstream fill site in Boring D-75-29, and 10 feet of shale were encountered at Elevation 544.8 IGLD in Boring D-75-14.

15. <u>SHORE PROCESSES</u>

The project site is located on a beach trending approximately north-northeastward and is exposed to a wide sector of westerly waves. Cattaraugus Creek enters the lake in the center of a 3-mile-long, gently arcuate embayment. The embayment has a sand-and-gravel beach extending from Hanover Bay at the south to Lotus Bay at the north end. Cattaraugus Creek is believed to be the primary source of littoral drift for the embayment. Other sources of littoral drift include Silver and Walnut Creeks and the material eroded from the bluffs to the southwest of Hanover Bay, and material from more remote beaches which bypasses these bluffs. The net direction of littoral drift in the area is from south to north. The direction of littoral drift was determined from lithological studies of the nearshore sediment composition. The littoral drift rate was estimated by wave-energy budget calculations to be approximately 40,000 cubic yards per year toward the north. Major storm waves from the westerly and southwesterly directions transport littoral drift northward. Reversals in the drift are caused by north-easterly wind-generated waves. The fetch distances to the north and northeast are considerably shorter than those from the southwesterly directions. Review of shoreline changes revealed by historic aerial photographs indicates that the shoreline along the embayment is in equilibrium, taking lake-level fluctuations into account. The developments behind beaches to the south of the project site are threatened by beach erosion damage due to high lake levels; however, the long-term net drift appears to be in balance with the sediment supply. Appendices B and F discuss the littoral regime and evaluate the impacts of the proposed improvements on littoral drift in more detail.

16. Littoral drift is presently transported by wave action into the creek mouth. During the summer, a bar builds in front of the creek mouth. Waves arriving obliquely to the shore transport the material laterally along the coast. River discharges during the spring and early summer maintain a relatively deep entrance channel. However, during the summer when creek discharge decreases, the waves tend to

gain control and build a bar across the creek mouth. By late summer, only a shallow channel exists which frequently is not deep enough for safe navigation. As the Cattaraugus sediment load is discharged into the lake, the coarser material scoured from the channel bed during high discharges is deposited near shore and the finer material is transported farther offshore. Plate 1 shows the bathymetry of the channel scoured by a flood. A bar formed by wave action off the creek mouth eventually migrates toward shore, and the material forms part of the beach to the north and south of the project site. During episodes of northerly wave attack, the littoral transport will be southward, and a portion of the Cattaraugus bedload will be transported to the southern end of the embayment. During episodes of southwesterly wave attack, the littoral transport will be northward. However, under these conditions, the shoals and land prominences to the southwest will refract wave energy in such a manner that the waves arrive with less energy and with directions nearly perpendicular to the shore along the south end of the embayment. Because these waves transport little material back to the north, some of the material from Cattaraugus Creek may become entrapped, forming the beach in this area. In summary, material is transported from Cattaraugus Creek and deposited on beaches to both the north and south, although the net direction of drift is northward.

17. As previously noted, the Cattaraugus Creek bed comprises a thin veneer of silty material overlying a sandy gravel. Only silty material is deposited during low discharges, but during higher discharges, all material is transported toward the lake in suspension and bedload. The rate of transport is dependent upon lake stage and creek discharge. During rising and high lake levels, a greater depth of water exists over the channel bed, reducing effective shear stresses and lowering rates of sediment transport. Under these conditions, more material tends to deposit in the creek bed than is scoured from it, and deposition occurs. As the lake level falls, the water depth decreases. This causes greater shear stress, and more material is scoured from the creek bed than is transported toward it from upstream sources. Under these conditions, relatively large quantities of littoral-drift material are carried into the lake. The elevation of the creek bottom and composition of bed materials are, therefore, a function of lake level at the project site. The seasonal rate at which the creek transports littoral-drift material into the lake is also a function of long-term lake level fluctuations, but the average annual rate is estimated to be approximately 30,000 tons. Dredging the channel will create a partial sediment trap, which will retard transport of this material into the lake. This could result in an erosion of the downdrift beach. Periodic dredging will be required to maintain the project depth and to nourish the downdrift beach. A project depth of 6 feet below prevailing lake level was selected as a minimum for navigation. Maintenance of

that depth will hold the annual dredging requirements to a minimum and yet provide adequate material to ameliorate the effects of the project on the adjacent beaches.

VI - OTHER PLANS INVESTIGATED

18. The breakwater types and armor-unit designs were selected from a study of alternative plans. Cellular steel sheet-pile and cantilever Z-pile breakwater alternatives were compared with rubblemound breakwater alternatives. The rubblemound alternatives were developed through secondary studies made to determine the least costly type of armor unit. Consideration was given to dolos and tribar concrete armor units and to quarry stone. The rubblemound structure was selected for detailed design as a result of these studies. Results of the subsurface explorations indicated that considerable difficulty would be encountered in driving sheet piles into and through the glacial till layer. This rendered the sheet-pile alternative infeasible from a cost basis. The cellular structure involved not only the driving problem, but also a high degree of risk due to the potential for scour of the channel. Both steel types would require toe protection, but a larger riprap section would be required for the cellular structure to protect it from toe scour. The first cost of the most economical of the cellular and cantilever sheet-pile combinations was $4,025,000, as compared to the first cost of the selected plan of $3,143,000. The annual costs were $172,500 and $168,800 for the sheet-pile and rubblemound alternatives, respectively.

19. Alternative studies were made to determine the least costly armor unit for the rubblemound structure. Costs of constructing the breakwater with dolos and tribar concrete armor units were compared with the cost of the quarrystone alternative. The analysis indicated that both concrete armor units were closely competitive with quarry stc e, but that the quarrystone alternative was the least expensive. Because of the closeness of the cost estimates, the request for bids should contain an option for using tribar or dolos units if stone prices increase or if acceptable stone is not in adequate supply at the time of bid solicitation. The materials survey indicates that acceptable stone is presently available in adequate supply.

20. Overtopping criteria required that the breakwater crest elevation be not lower than +14 feet LWD. Provision of recreational fishing benefits required that a walkway be installed along the crest of the south breakwater. Alternative rubblemound breakwater sections were compared to select the one that most economically met the above objectives. Two walkway alternatives, Berea limestone blocks fitted along the center of the crown and a concrete-grout path, utilized the

full-height rock section. An alternative was devised for a smaller rock section with a massive concrete cap built to +12 feet LWD and extended to the required +14-foot LWD crest elevation, with a 2-foot high parapet. The latter section proved to be the most economical on a first cost and annual cost basis and was selected for detailed design.

VII - DESCRIPTION OF THE PROPOSED STRUCTURES AND IMPROVEMENTS

21. BREAKWATERS

The proposed improvements include construction of an 1,850-foot long breakwater on the south side of the creek mouth and a 600-foot long breakwater on the north side. The proposed plan configuration is shown in Plate 1. Detailed sections and profiles are shown in Plate 2. The breakwaters are rubblemound with large quarrystone armor. The south breakwater has a massive concrete cap, which provides a walkway for fishermen at Elevation +12 feet LWD, with a 2-foot parapet. The side slopes for the trunk section are 1:1.5. Side slopes for the head section are flattened to 1:2 to maintain the stability of the armor without increasing the required stone size. The design lake level of +8 feet LWD has a 20-year recurrence period. The height of the design breaking wave at the south breakwater is 11.7 feet, its period is 7.8 seconds, its direction is from the northwest, and its recurrence interval is 20 years. The design wave at the north breakwater is decreased to 9 feet because of the shallower water depths and the protection afforded by the south breakwater. Armor stone for the south breakwater ranges from 1 to 6 tons, and for the north breakwater, from 1 to 3 tons.

22. The south breakwater is rooted on a sand dune at Elevation +12 feet LWD, extends lakeward on a 330-degree azimuth to Station 12+50, and thence curves toward the north tending to parallel the shore near the head section at Station 18+50 where the lake bottom is -9 feet LWD. The purpose of the alignment is to provide adequate protection from the large storm waves approaching from the southwest quadrant and to prevent the predominant northward littoral drift from entering the harbor. The northward facing entrance allows the sediment load of the creek to deposit in shallow water where it may be transported shoreward by wave action to the downdrift littoral zone.

23. The north breakwater is rooted on a sand spit whose elevation is about +8 feet LWD, and it extends 600 feet lakeward on a 307-degree azimuth to its head where the lake bottom is -7 feet LWD. The breakwater crest elevation is +10 feet. Lying in the shadow of the south breakwater for most of the incident waves, this breakwater is exposed to less severe wave impact. Its primary purpose is to prevent littoral

drift and windrowed ice from blocking the navigation channel. Although the net littoral transport is from south to north, reversals of drift direction would tend to form a fillet of sand at the creek mouth. A breakwater configuration similar to the plan shown in Plate 1 was tested in a hydraulic model study. The tests showed that ice would not jam between the breakwater heads.

24. Profiles taken through the north and south breakwaters shown in Plate 2 indicate that the present ground line will abut underlayer and armor layers. These layers have large voids which, with the aid of wave action, could permit transport of littoral drift through the breakwaters. The underlayer and armor layers are to be rendered sandtight in these areas by placing a filter cloth membrane along the axis of each structure, as shown in the drawings. The core material should be sufficiently impermeable to sand to prevent its passage through the breakwater in the deeper water areas. The filter material is to be placed along breakwater stations which will be abutted by a fillet as a fillet accretes.

25. <u>BERM</u>

The north breakwater is rooted to a low sand spit that is subject to erosion by the lake waves and creek currents. An armored berm along 550 feet of this spit is designed to connect the root of the north breakwater to higher ground. The plan configuration is shown in Plate 1, and the profile and typical sections are shown in Plate 2. The berm has 1-ton armor stone on the lake side with a 1:2 side slope and 200-pound riprap on the creek side, also with a 1:2 side slope. The 1-ton armor is stable for waves as high as 6 feet and the 200-pound stone is stable for a mean channel velocity of 13.8 fps. A filter layer is to be placed over the in-situ sand to prevent the fines of the base material from being pumped up through the armor and underlayer stones. The filter may be either a stone product or a plastic woven cloth. The design is based on a graded stone filter. A +11-foot LWD crest elevation was selected, based on a wave runup analysis. The berm constructed to this elevation may be subjected to minor and infrequent overtopping. On the lake side the armor extends down to LWD to protect the structure against potential shoreline retreat during episodes of deficient littoral nourishment along the downdrift beach. On the creek side the armor extends down to -4 feet LWD to protect the berm from possible scour induced by currents flowing from the side channel into the main channel. The armor on the creek side of the berm at the rounded transition to the breakwater is increased to 1-ton stone. Here, larger armor is required because of the hazards of floating debris and locally higher currents.

26. CHANNELS

The channel dimensions were selected to meet the needs of small-boat navigation and to reduce excavation quantities sufficiently to minimize adverse environmental impacts. The channel, shown in Plate 1, is 5,000 feet long. The entrance channel is 200 feet wide and has a project depth of -5.5 feet LWD. The channel in the outer basin is 100 feet wide and has a project depth of -5.5 feet LWD. This project depth results in a minimum summer navigation depth of 8 feet of water during present lake levels. The project depth decreases in the creek to a depth of 6 feet of water. A depth of 6 feet of water was selected based on requirements of small boats presently using the creek. A project depth of -3.5 feet LWD was selected for design, inasmuch as this depth results in 6 feet of water during the summer navigation season. The lake level during project formulation was +4.0 feet LWD during the high lake levels of spring. Allowing 1.5 feet for seasonally lower levels, a -3.5 foot project depth would result in 6 feet of water during the current seasonal low levels. This project depth should, of course, be adjusted occasionally with long-term lake-level changes. Annual maintenance would cost considerably more with project depths of -6 feet and -8 feet LWD during high lake levels because with the high sediment discharge rate in Cattaraugus Creek, the deeper channel would create a more efficient sediment trap resulting in greatly increased maintenance requirements.

27. The re-curved spit located on the north side of the creek mouth should be removed in order to preclude the possibility of the material in the spit filling the navigation channel during a flood. Additional compensating excavation on the south of the creek bank at the mouth will be performed to prevent overbank flooding to occur for a discharge of 22,000 cfs. This material may be used as bedding for the breakwater or it may be placed directly on the downdrift beach.

28. Riprap is required to stabilize the channel bottom in the outer basin along the basin side of the south breakwater. A riprap heel protection is shown in Plate 1 to extend from Station 11+00 to Station 18+50. One-half ton riprap is to be placed over a filter material to prevent a 20-year recurrence discharge of 40,000 cfs from undermining the breakwater heel. The design mean channel velocity is 13 fps. Shears on the outer bank of the bend are increased by a factor of 1.8.

29. RECREATIONAL FACILITIES

A massive concrete cap provides a walkway for fishermen along the crest of the south breakwater. A parapet is designed on the lake side of the breakwater. The wall is 2 feet higher than the cap. Each cap segment is 15 feet long. Parapet sections are designed to be two feet shorter on each cap section to allow accesses for fishermen onto the breakwater side slope for fishing purposes. A handrail is provided on the basin side of the crest for safety. Parking and sanitary facilities are presently available on the south side of the creek.

30. NAVIGATION AIDS

Navigation lights are required on the head sections of both breakwaters. The lights are to be battery-operated and will be installed by the U. S. Coast Guard. The lights will be affixed to a metal frame which will be anchored to a base on the breakwater crest. The massive concrete cap provides the base for the south breakwater. The thickness of the cap is increased from 3 feet to 5 feet in the base area, and anchor bolts are to be set in the concrete. A concrete cap section 5 feet thick is designed for the north breakwater on the head section and to provide the navigation light-stand base.

VIII - CONSTRUCTION PROCEDURES

31. The project requires construction of two breakwaters, a berm, and channel dredging and riprap protection. The following construction procedure illustrates one feasible method of accomplishing construction at a reasonable cost to the Government. The procedure includes placing half of the breakwater material in the south breakwater first, with a land-based operation. Material will be transported to the project site by rail and transferred to truck at a siding. The partially constructed south breakwater will then provide partial protection from waves to facilitate construction of the berm and north breakwater. A second crew will begin construction of the north breakwater. The construction sequence involves excavation of the loose overlying alluvial material, placement of the bedding obtained from the spit or channel dredging, and then successive placement of core, underlayer, and armor stone. The filter cloth membrane is to be placed from Stations 2+00 to 7+00 in the south breakwater underlayer and from Stations 0+00 to 3+00 in the armor layer and underlayers of the north breakwater. The filter will be placed in 1 to 3 feet of water. Some placing difficulty is anticipated, as it must be coordinated with stone placement. Nevertheless, this is a possible and necessary step. The cloth must be draped over the stones in loose folds so that it will not be stretched and torn during placement of adjacent and overlying stones as the work proceeds.

32. Placement of the crest cap stone layer may be deferred to provide a wider construction road. This procedure will allow faster placement of the underlying materials and will result in a lower rate of material loss due to wave action during construction. The channel riprap on the basin side of the south breakwater should be placed concurrently

with the breakwater construction along the adjoining stations. The probability of a high peak discharge during the summer is low; however, even a moderate flow could scour the breakwater heel and endanger the entire structure. As a final phase of the rubblemound construction, the cap stone is placed from the lakeward end of each breakwater toward shore.

33. The navigation light bases and the concrete cap on the south breakwater are to be installed during the latter part of the contract performance period. The concrete cap is to be constructed by building a form 3 feet high around each cap section for the initial pours. The forms are to be 5 feet high for the navigation light bases. The forms are affixed to the rubblemound by drilling holes and inserting pins into the cap stone. Sand and gravel taken from the spit or channel excavations in combination with burlap bags or plastic membrane are used to chink the voids in the breakwater cap stone and gaps between stone and form in order to prevent excessive loss of concrete during the pour. Although the sand and gravel will eventually wash out of the voids during subsequent wave attack, it will serve its purpose at the time of construction. The 15-foot x 15-foot cap sections are poured in alternating sections. Braces employed on the end forms are to be removed. A 2-inch gap between cap sections is then created by placing removable shims between the set concrete and forms prior to pouring the alternate sections. Reinforcing bars are embedded in the wet concrete for anchoring the parapet, which is then constructed in a later pour. The concrete surface must be roughened in the parapet segments to be cap sections. The surface of the walkway should be rough-finished to provide safe footing and crowned slightly for drainage. Anchor bolts are also installed in the wet concrete for the handrail stanchions. Two cap segments can be poured each day. A 14-day curing period is required to allow the concrete to develop adequate strength before vehicular traffic over the cap is permitted. When the parapet walls are poured, they can be constructed using eight re-usable forms per day. The handrail can be placed concurrently with parapet construction. The navigation lights can be placed 28 days after the bases have been poured.

34. Armoring of the sand berm requires that base material be excavated. Stone used in the construction of the berm will displace approximately 10,000 cubic yards of in-situ sand and gravel. The placing rig can backfill the trench as it works, and the excess material can be used for beach nourishment, for breakwater bedding material, or for chinking under the cap sections if the operations are concurrent.

35. The channel would probably be constructed during the final year. The channel dredging should be deferred until June, which is after the spring flooding. Three months are required to dredge the channel,

based on using a 300 HP, 14-inch hydraulic dredge. The spoil material is to be placed on the downdrift beach. Some of the spoil may also be used for cap chinking if needed and found suitable. The spoil to be used for chinking should be stockpiled near the breakwater and the remainder distributed along the north beach.

IX - ENVIRONMENTAL ANALYSIS

36. The plan of improvement includes removal of bottom sediments from the creek and lake. The procedure for removing the material and requirements for spoil disposal depend on whether or not the material is polluted. A 1972 analysis indicated that the creek-bed material was polluted and would not be acceptable for placement on the beach. However, the sampling techniques and criteria have changed from 1972 to 1975. The 1975 study by the EPA indicated that grease and oil exceeded criteria in the gravelly river sediments, but the material is not otherwise significantly polluted. Consequently, the material is considered suitable for beach nourishment. Radioactive material had been believed discharged into the creek, possibly contaminating the sediment. Preliminary analysis of the samples of sediments to be dredged showed the emitted radiation to be well below unacceptable levels. Therefore, it will not be necessary to contain the dredged material. The borrow area contains a layer of silt and larger fraction of sands and gravels. The coarser material to be dredged from the creek would eventually deposit on the beach under natural conditions. The dredging will alter only the method by which the material is transported to the beach. Under natural conditions, the fines are transported lakeward in suspension and deposited in deeper water. Under dredging practice, the fines will be deposited on the beach and then intermittently transported lakeward. Turbidity will be created during the dredging operation. The turbidity in the creek will be temporary, lasting the duration of dredging. The turbidity in the lake will occur as waves wash the fines from the fill. This effect will continue for a while after construction, but will abate in time, leaving the beach covered with sand and gravel similar to the present natural beach material.

37. The environmental and sociological effects of the plan will generally be to enhance the recreation opportunities afforded boaters and fishermen and to enhance the living conditions of nearby residents by eliminating ice jams and thereby providing a measure of flood protection. The breakwaters will prevent bar formation across the creek mouth and render the stream more accessible to spawning fish. Ice jams in the creek mouth that have caused flooding in the winter and early spring should not occur after project completion. The rubble breakwaters will cover existing benthic habitat; however, they will also provide new aquatic habitat. Channel dredging may remove some existing benthic habitat, but these should reestablish.

38. Removal of the spits in the basin on the north and south sides of the creek mouth will enhance water circulation and water quality in the lagoon.

39. The south breakwater should impound littoral drift on the south beach, widening it and thereby benefiting nearby home owners and park users. The beach to the north will be subject to erosion if not adequately maintained, possibly resulting in a loss of land area immediately to the north of the north breakwater. This beach has no homes or structures, and any land loss there would have minor impact. However, project plans call for periodic nourishment of the downdrift shore, thus assuring maintenance of the threatened beach segment. Sufficient nourishment material for this purpose will be readily available from periodic channel maintenance. As illustrated and described in Appendix B, erosion of the downdrift beach is not predicted to occur too rapidly. Consideration of both the availability of nourishment material and the relatively slow rate of erosion expected makes any permanent protection economically unjustifiable. Further, periodic nourishment is the better solution from environmental and social viewpoints.

40. Preceding paragraphs analyze the environmental impacts of the plan presented in this GDM. The plan differs very little, as regards environmental impacts, from that presented in the Phase I GDM and in the Environmental Impact Statement that has been filed with the President's Council on Environmental Quality. The primary differences between the Phase I GDM plan and the Phase II GDM plan, and the differences in environmental impacts, are outlined below:

a. The orientation and makeup of the breakwaters has been changed based on the conclusions of the hydraulic model study (See Appendix A) from aligning southwest to northwest, and from steel sheet pile to rubblemound. As a result of these changes, the environmental impact is not altered since the area of benthic habitat disturbed remains the same. In fact, rubblemound construction is ecologically advantageous because it provides additional and more variable habitat.

b. The project channel depth has been decreased, reducing the quantity and area of benthic habitat removed and therefore lessening impact on the creek.

c. The levees are no longer required and a parking lot, comfort station and access road are already provided on the south side of the creek. This will reduce the amount of lands required for this project thus preventing a commitment of open space to developmental uses.

X - ACCESS ROADS

41. Temporary access is required for construction and maintenance of project features. Existing roads are adequate for construction access. The south breakwater requires a 100-foot extension of Allegheny Road to the sand dune. This property is owned by the town of Hanover. The sand berm and north breakwater are accessible by an existing dirt road which borders a side channel to the north of the main channel and approaches the site north of the berm. Minor maintenance of this road will be required by the Contractor. The cost of this road maintenance has been incorporated in the cost estimate in unit prices. The channel will not require an access road because it will be dredged by floating plant.

XI - CONSTRUCTION MATERIALS

42. The breakwater requires a 6-ton, 165 pcf minimum density angular quarry stone. Five possible sources within a 100-mile radius of the project site can produce stone meeting the armor-unit requirements. Underlayer, core, riprap, and filter materials and fine and coarse concrete aggregate are obtainable either from project excavations or from several other sources within a 50-mile radius of the project site. A materials survey was performed to identify sources and present results of tests performed on samples and experience records of the sources. The results of the materials survey are presented in Appendix C, Geology, Soils, and Construction Materials.

43. The bedding material for the breakwaters may be obtained from spit material to be removed in project construction on the north and south sides of the creek mouth, from excessive berm excavation, or from creek dredging. These same materials are suitable for chinking voids in the breakwater crest under the concrete cap and for nourishment of the downdrift beach.

44. The project construction will also require reinforcing bars, concrete, pipe stanchions, form lumber, form oil, form rails, safety-rail chain and stanchions, and plastic filter cloth for the diaphragm in the breakwaters. These materials are readily available through appropriate suppliers.

XII - ENVIRONMENTAL QUALITY ENHANCEMENT MEASURES

45. The breakwater and berm construction occurs in the lake or on the beach. No vegetation is to be planted in the beach areas. The breakwaters will enhance fishing opportunities and provide aquatic habitat in the voids created by the rubblemound. Deepening of the channel and removal of the spit will enhance water quality, expand boating opportunities, and assure easy access for spawning fish.

XIII - REAL ESTATE REQUIREMENTS

46. The authorizing document requires that local interests provide all lands, easements, and rights-of-way required for construction and maintenance of the structures and improvements. The lands in the lake required for the breakwaters and outer channel are owned by the State of New York. A 20-foot-wide permanent easement around the periphery of the breakwaters and channels and an additional 20-foot temporary construction easement is required as shown in Plate 3. The south breakwater connects to shore on the beach owned by the town of Hanover which must provide the temporary and permanent easements needed for this construction. The berm and north breakwater sites are on the Seneca Indian Reservation. Permanent easements are to be purchased for the structures and the dredged spit, and rights-of-way are to be provided along the existing dirt road for construction and maintenance. Approximately 8.5 acres of easements are to be provided by the local interests at a cost estimated at $11,000.

XIV - RELOCATIONS

47. No relocations of roads, highways, railroads, power, telephone, sewer, or water lines are required for construction and maintenance of the project.

XV - COST ESTIMATES

48. FIRST COSTS

The total first cost for the Cattaraugus Creek project is $4,899,000, based on September, 1975, price levels. Of this cost, $3,113,500 are to be borne by the Federal Government and $1,785,500 by local agencies. Table 1 lists the itemized cost for each project feature, the apportionment of costs to Federal and non-Federal agencies, and the allocation of costs to multipurpose, navigation, flood control, and recreational fishing features.

49. COMPARISON WITH PREVIOUS COST ESTIMATES

Table 2 presents comparisons of cost estimates for each subfeature for the Project Document, Phase I General Design Memorandum, latest approved Government estimate, and the present plan. The first cost of $4,899,000 for the present plan is less than the latest approved Government estimate, October 1975, of $5,800,000 and the Phase I General Design Memorandum estimate, September 1974, of $5,234,000. Price changes are due to changes in price levels, construction techniques, EPA criteria for dredge-spoil disposal, and minor changes in navigation requirements. Price levels were assumed to increase according to the ENR construction index which increased 8.4 percent from September 1974, to September 1975. Contingencies were 20 percent in the Phase I General Design Memorandum and 12 percent in the present estimate.

Table 1 - Cost Estimate
(Sept. 1975 Price Levels)

Item	Quantity	Unit	Unit Cost	Amount	Total
			$	$	$
FEDERAL (C of E)					
CHANNELS					
Excavation	35,000	C.Y.	4.60	161,000	
Spit Excavation	36,900	C.Y.	1.75	64,600	
Riprap (R.5)	7,500	Tons	23.00	172,500	
Filter (F2)	2,600	Tons	11.00	28,600	
Contingencies		L.S.		48,300	
TOTAL				475,000	
BREAKWATERS					
South B/W					
Excavation	14,100	C.Y.	1.30	18,300	
A6 Armor Stone	30,000	Tons	30.50	915,000	
A4 Armor Stone	8,400	Tons	29.00	243,600	
A1 Armor Stone	1,400	Tons	26.50	37,100	
B.6 Quarry Stone	5,300	Tons	23.00	121,900	
B.4 Quarry Stone	1,200	Tons	23.00	27,600	
C1 Core	25,500	Tons	20.30	517,700	
Bedding	5,500	C.Y.	8.50	46,800	
Concrete	3,300	C.Y.	125.00	412,500	
Rebar	1,600	Lbs.	0.45	700	
Filter Cloth	3,000	S.F.	0.50	1,500	
Contingencies		L.S.		280,300	
TOTAL				2,623,000	
North B/W					
Excavation	3,000	C.Y.	1.30	3,900	
A3 Armor Stone	8,700	Tons	27.70	241,000	
A1 Armor Stone	700	Tons	26.50	18,600	
B.3 Quarry Stone	1,500	Tons	23.00	34,500	
C1 Core	7,400	Tons	20.30	150,200	
Bedding	1,700	C.Y.	8.50	14,500	
Filter Cloth	2,000	S.F.	0.50	1,000	
Contingencies		L.S.		56,300	
TOTAL				520,000	
SUBTOTAL BREAKWATERS				3,143,000	

Table 1 (Cont'd)

Item	Quantity	Unit	Unit Cost	Amount	Total
			$	$	$
BERM					
Excavation	26,500	C.Y.	1.00	26,500	
Backfill	16,600	C.Y.	1.00	16,600	
Disposal	9,900	C.Y.	1.00	9,900	
Al Armor Stone	6,000	Tons	26.50	159,000	
B.1 Quarry Stone	5,600	Tons	23.00	128,800	
Fl Filter Stone	4,100	Tons	11.00	45,100	
Contingencies		L.S.		46,100	
TOTAL				432,000	
RECREATION					
Handrail	1,850	L.F.	7.50	13,900	
Contingency		L.S.		2,100	
TOTAL				16,000	
ENGINEERING & DESIGN				473,000	
SUPERVISION & ADMINISTRATION				329,000	
TOTAL				4,868,000	
LESS CASH CONTRIBUTION					
Navigation				1,766,500	
Recreation				8,000	
TOTAL				1,774,500	
TOTAL (C of E)				3,093,500	
FEDERAL (U.S.C.G.) NAVIGATION AIDS					
Lights	2	L.S.		20,000	
TOTAL FEDERAL					3,113,500
NON-FEDERAL LANDS				11,000	
CASH CONTRIBUTION					
Navigation				1,766,500	
Recreation				8,000	
TOTAL				1,774,500	
TOTAL NON-FEDERAL					1,785,500
TOTAL PROJECT FIRST COST					4,899,000

Table 2 - Comparison of First Cost Estimates

Item	Project Document Sept. 1964	Phase I GDM Sept. 1974	Latest Approved Oct. 1975	Present Sept. 1975
	$	$	$	$
FEDERAL				
Channels	608,400	1,560,000	1,718,000	475,000
Breakwaters, Berm	879,000	2,700,000	2,969,000	3,575,000
Levees	32,600	104,000	115,000	
Recreational Facilities	60,000	120,000	131,000	16,000
Engineering & Design	140,000	415,000	473,000	473,000
Supervision & Administration	120,000	275,000	329,000	329,000
GROSS CONST. COST	1,840,000	5,174,000	5,735,000	4,868,000
LESS CASH CONTRIBUTION				
For Navigation	520,000	1,692,000	1,871,000	1,766,500
For Recreation	30,000	60,000	74,000	8,000
SUBTOTAL	550,000	1,752,000	1,945,000	1,774,500
TOTAL FEDERAL (C of E)	1,290,000	3,422,000	3,790,000	3,093,500
AIDS TO NAVIGATION	7,500	50,000	55,000	20,000
TOTAL FEDERAL FIRST COST	1,297,500	3,472,000	3,845,000	3,113,500
NON-FEDERAL				
CASH CONTRIBUTIONS				
For Navigation	520,000	1,692,000	1,871,000	1,766,500
For Recreation	30,000	60,000	74,000	8,000
LANDS AND DAMAGES	5,000	10,000	10,000	11,000
TOTAL NON-FEDERAL FIRST COST	555,000	1,762,000	1,955,000	1,785,500
TOTAL PROJECT COST	1,852,000	5,234,000	5,800,000	4,899,000

50. The quantity of dredged material has been reduced from 116,000 cubic yards to 71,900 cubic yards. The present estimate includes 36,900 cubic yards to be removed from the north and south spits. This item was not included in the Phase I estimate. The Phase I plan included a cost of $12.00/C.Y. to transport polluted spoils to a disposal area. Subsequent to the Phase I plan, the EPA conducted a more detailed survey, and it was determined that the proposed dredged materials were suitable for beach nourishment or open-lake disposal. Elimination of the spoils transportation was the largest reduction in cost for the project. Reducing the creek project depth from -6 feet LWD to -3.5 feet LWD, or 6 feet of water, and the entrance depth from -8 to -5.5 feet LWD reduced the quantity of dredged material in the outer channel by a factor of more than one-half. The net change resulting from the above considerations reduced the project first cost by $1,085,000. However, the requirement to line the outer channel to prevent excessive scour increased the first cost by $225,000, making the net decrease in cost for channels $860,000.

51. The alternative study analysis indicated that rubble breakwaters would be less costly than sheet-pile breakwaters. The Phase I plan had a cellular steel sheet-pile breakwater with a 10-foot crest elevation and a sand berm armored on the creek side only. The present rubblemound plan has the crest elevation of the north breakwater at +10 feet LWD, and the berm is armored on the lake and creek sides; however, the crest of the south breakwater was raised to +14 feet LWD. The alignment of the breakwaters changed considerably. The aggregate length of the breakwaters increased 150 feet from 2,300 feet to 2,450 feet. The net effect of the above changes increased the breakwater and berm construction cost estimate by $875,000, from $2,700,000 to $3,575,000.

52. The alignment of the breakwaters, placing the longer breakwater on the south side of the creek, changed the requirements for recreation. The previously designed comfort station, parking lot, and access road are not required with the present plan, because these features are presently available on the south side of the creek. This resulted in a savings of $45,000 including contingencies. The walkway and safety rail designs changed with changes in the alignment and breakwater construction type. The handrail and walkway, including contingency, were estimated to cost $75,000 in the Phase I report. The recreation facilities are presently estimated to cost $16,000. The change in design results in a net savings of $104,000 for recreational facilities.

53. Costs for Engineering and Design and for Supervision and Administration were based on percentages of construction cost used in the latest approved Government estimate. Minor changes due to price level increases were included. The U. S. Coast Guard estimate for the navigation-aid bases, frames, and lights has been reduced from $50,000 to $20,000. The required lands increased by $1,000, from $10,000 to $11,000, based primarily on a more detailed estimate of the requirements.

XVI - SCHEDULES FOR DESIGN AND CONSTRUCTION

54. The schedule for design and construction is given in Table 3. Two construction seasons are required to complete the project. The construction sequence is discussed in more detail in Section VIII.

Table 3 - Construction Schedule

Item	Duration
Plans and specifications	4 months
Advertise and award construction contract	3 months
Construction	Two construction seasons

XVII - OPERATION AND MAINTENANCE

55. The annual maintenance costs for the multipurpose project are summarized in Table 4. The total annual maintenance costs allocated to both navigation and flood control of $90,900 is comprised of costs for three purposes - channels, breakwaters - berm, and aids to navigation. The cost of channel maintenance includes $57,700 to maintain the project depth. This is based on the need to remove from the creek bed and deposit on the downdrift beach to the north an average annual 10,000 cubic yards of material. An additional $2,300 is estimated to maintain the channel riprap for a total of $60,000 for channel maintenance. Maintenance is also occasionally required to reset and replace damaged stones in the breakwater and berm. The average annual cost of this work is estimated at $29,000. For navigation light operations an average annual cost of $1,900 is estimated.

56. Maintenance of the recreational features requires repairs to the pipe stanchions and safety rail. A cost of $1,600 per year was apportioned to local agencies for recreational-feature maintenance.

57. The project requires $92,500 for annual maintenance. Local agencies are responsible for $25,800 and the Federal Government is responsible for $66,700. Maintenance cost apportionments are summarized in Table 5 for Federal and non-Federal agencies. Apportionments of these maintenance costs were determined by an analysis of separable costs and benefits.

XVIII - BENEFITS

58. GENERAL

Benefits from the Cattaraugus Creek harbor project include those resulting from small-boat navigation enhancement, flood control, area redevelopment, and recreational fishing improvements. The benefits have been updated from the Phase I General Design Memorandum to account for changes in the project plan and price levels. The following summarizes the benefits and changes.

59. NAVIGATION

Benefits attributed to navigation were evaluated as the gain in annual return, as a result of the improvements, which owners of pleasure craft would receive 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. An estimate was made of the percentage of optimum use of the boats received presently by the owners and the percent of optimum use anticipated with the improvements. The difference is considered to be the gain in percent of optimum use resulting from the harbor improvements. The navigation benefits were taken as the sum of benefits attributed to increased usage of existing boats, the addition of new boats, increased number of trailer-drawn boats, increased visits by transient boats, and the use of the project improvements as a harbor of refuge. Table 7 summarizes the navigation benefits. The estimate of benefits for the present study was made by updating the benefits calculated for the 1974 Phase I General Design Memorandum. A boat count was conducted in July, 1975, which showed an increase in the moored fleet from 253 boats to 263. The benefits for the locally based fleet were estimated to be proportional to the increased number of boats plus an 8.4 percent increase in value for price level increase. The remaining benefits were updated to account only for price level increases. The navigation benefits were estimated to be $242,000.

Table 4 - Maintenance - Multipurpose Project

Item	Multi-purpose	Flood Control	Navigation
	$	$	$
Channels	60,000	60,000	60,000
Breakwaters, Berm	29,000	29,000	29,000
Recreational Facilities	1,600	-0-	-0-
Aids to Navigation	1,900	1,900	1,900
TOTAL	92,500	90,900	90,900

Table 5 - Apportionment of Maintenance Costs

Item	Federal	Non-Federal	Total
	$	$	$
Navigation	66,700	-0-	66,700
Flood Control		24,200	24,200
Recreational Facilities		1,600	1,600
TOTAL	66,700	25,800	92,500

60. FLOOD CONTROL

Construction of the breakwaters will eliminate the sand bar formation at the mouth of Cattaraugus Creek and reduce the probability of ice jamming at the creek mouth. Elimination of the ice-jam induced backwater will be the only flood control benefit. Table 6 lists the average annual damages and benefits for two river reaches in the lower stream section of the project. Reach 1 is the Sunset Bay area on the south side of the creek, and Reach 2 is in the Indian Reservation on the north side of the creek at Snow's Marina. The breakwaters will eliminate high stages caused by ice jams; however, damages will still occur due to high stages during high discharges under free-flow conditions. Benefits were calculated in Table 6 by subtracting the damage during free flow from that attributed to stages induced by ice and free flow. The benefits that will accrue from the project are the difference between the existing ice-jam plus free-flow damages and the free-flow condition. The resulting flood-control benefits, updated from 1972 to 1975, are $89,320.

Table 6 - Estimated Average Annual Flood Control Benefits

Reach	Average Annual Damages from Ice and Free Flow June 1972	Average Annual Damages from Free Flow June 1972	Average Annual Benefits June 1972	Average Annual Benefits Sept. 1975
	$	$	$	$
1	54,210	18,970	35,240	44,760
2	48,540	13,450	35,090	44,560
TOTAL	102,750	32,420	70,330	89,320

Table 7 - Increased Boating Opportunity
Increased Usage Days for Existing Boats
Increase in Number of Boats
(September, 1975)[1]

	Return: Improved Conditions	Return: Existing Conditions	Benefits
			$
Present Fleet	263 Boats[2]	(Sunset Bay)	
Average Value $1,376,555	(8 to 12%)	(4 to 6%)	68,800
New Fleet	155 Boats	(10 year growth)	
Average Value $908,934	(8 to 12%)	0	67,800
Transferred Boats	215 Boats	(10 year growth)	
Average Value $2,045,000	(8 to 12%)	(4 to 6%)	69,900
Transient Boats	3 equivalent	Immediate Development	
$45,528	(8%)	(4%)	2,000
Existing Trailer-Drawn	14 equivalent	(Sunset Bay)	
$42,500	(12%)	(6%)	2,500
Future Trailer-Drawn	110 equivalent	Immediate Development	
$333,900	(12%)	(6%)	20,000
TOTAL INCREASED BOATING OPPORTUNITY			231,000
TOTAL NAVIGATION BENEFITS			242,000

[1]Update by 8.4% for price level increase.

[2]Change present fleet from 253 to 263, based on 1975 boat count.

61. AREA REDEVELOPMENT

Chautauqua County, NY is designated as a redevelopment area under Title IV(S) of the Public Works and Economic Development Act of 1965 (PL 89-136). The project construction will provide increased employment in the area, involving 200 man months of skilled and 50 man months of unskilled on-site labor. The average annual area redevelopment benefits for the present project were updated from $34,400 in the Phase I General Design Memorandum to $37,300 on the basis of price-level increases.

62. RECREATIONAL FISHING BENEFITS

Recreational pier fishing benefits were estimated by the U. S. Fish and Wildlife Service in September, 1964, at $16,500. The same benefits were used in the Phase I General Design Memorandum. The project has not undergone significant changes in the fishing opportunities, except those due to increased stocking programs. The present benefits are estimated to be $17,900, incorporating a price increase for 1974.

63. SUMMARY

Table 8 summarizes the annual benefits for the 1964 project document plan, the Phase I Design Memorandum plan, and the present project plan. The benefits of the present project plan are $386,520. The benefit/cost analysis is presented in Table 9. The overall benefit/cost ratio is 1.30.

Table 8 - Annual Benefits

Purpose	Interim Report Sept. 1964	Phase I General Design Memorandum Sept. 1974	Present Project Sept. 1975
Navigation	81,800	217,500	242,000
Flood Control	51,900	104,350	89,320
Area Redevelopment	-0-	34,400	37,300
Recreational Fishing	16,500	16,500	17,900
TOTAL	150,000	372,750	386,520

Table 9 - Benefit/Cost Ratio

Period	Annual Benefits	Annual Charges	B/C Ratio WO/AR	B/C Ratio W/AR
Interim Report, December 1964 @ 3-1/8% Interest	150,200	114,900	1.31	--
Phase I General Design Memorandum @ 3-1/4% Interest	372,750	272,800	1.24	1.37
Phase II General Design Memorandum @ 3-1/4% Interest	386,520	298,400	1.17	1.30

XIX - COST ALLOCATION

64. The allocation of costs to the project purposes of navigation, flood control, and recreational fishing are required to determine the apportionment of Federal and non-Federal participation. The allocation of costs, exclusive of the recreation costs, to the primary purposes of navigation and flood control are summarized in Table 10. Costs were allocated by developing alternative costs for each project purpose, separable costs, and remaining benefits. Costs were allocated on the basis of a percentage of the cost of individual-objective projects relative to the multipurpose project. The allocation of first costs, investment costs, and annual costs for the Federal and non-Federal participation are summarized in Table 11.

65. The first cost allocated to navigation is $3,561,000. The non-Federal cash contribution is computed by taking 50 percent of the total remaining after subtracting $20,000 for Federal aids to navigation and the lands costs allocated to navigation of .7292 x $11,000 or $8,000. Therefore, the non-Federal cost share for navigation = $1,766,500. The total non-Federal first cost ($1,777,500) responsibility also includes all lands = $11,000 and recreation first costs described in paragraph 67 following. The maintenance annual costs for navigation of $66,700 are to be borne by the Federal Government.

66. The first cost of the flood control project, is $1,322,000. Local interests are required to maintain the flood control project at an annual cost of $24,200.

67. The recreation first costs, totalling $16,000 are to be shared equally by the Federal Government and local agencies. The local interests are responsible for $1,600 annually for maintenance of the handrail.

Table 10 - Allocation of Costs to Primary Purposes

Item	Navigation	Flood Control	Multi-purpose
	$	$	$
ALLOCATION COMPUTATION			
First Costs, Alternative Projects	4,883,000	4,883,000	4,883,000
Annual Charges, Alternative Projects	296,200	296,200	296,200
Annual Maintenance, Alternative Projects	90,900	90,900	90,900
TOTAL ANNUAL BENEFITS	242,000	89,320	331,320
CHARGES, M-PP			
1. Benefits	242,000	89,320	
2. Alternate Costs	296,200	296,200	
3. Benefits Limited by Alternate Costs	242,000	89,320	
4. Separable Costs	2,700	0	2,700
5. Remaining Benefits	239,300	89,320	328,620
6. Percent Distribution of Item 5	72.82%	27.18%	100.00%
7. Allocated Joint Costs	213,700	79,800	293,500
8. Total Allocation	216,400	79,800	296,200
ALLOCATION OF MAINTENANCE, M-PP			
9. Separable Costs	1,900	0	1,900
10. Percent of Joint Costs, Item 6	72.82%	27.18%	100.00%
11. Allocated Joint Costs	64,800	24,200	89,000
12. Total Allocation	66,700	24,200	90,900
13. Allocated Annual Charges	216,400	79,800	296,200
14. Allocated Maintenance	66,700	24,200	90,900
15. Remainder	149,700	55,600	205,300
16. Percent Distribution of Item 15	72.92%	27.08%	100.00%
17. Allocated First Costs	3,561,000	1,322,000	4,883,000

Table 11 - Allocation of Costs

Item	Navigation	Flood Control	Recreation	Total
	$	$	$	$
ALLOCATED FIRST COSTS				
Federal	1,786,500	1,319,000	8,000	3,113,500
Non-Federal	1,774,500	3,000	8,000	1,785,500
TOTAL	3,561,000	1,322,000	16,000	4,899,000
INVESTMENT COSTS				
Federal	1,844,000	1,362,000	8,000	3,214,000
Non-Federal	1,832,000	3,000	8,000	1,843,000
TOTAL	3,676,000	1,365,000	16,000	5,057,000
ANNUAL COST				
Interest & Amortization				
Federal	75,000	55,500	300	130,800
Non-Federal	74,700	100	300	75,100
Maintenance	66,700	24,200	1,600	92,500
TOTAL	216,400	79,800	2,200	298,400

XX - STATEMENT OF FINDINGS

68. I have reviewed and evaluated, in light of the overall public interest, documents concerning the proposed action, as well as the stated views of other interested agencies and the concerned public, relative to the various practicable alternatives in accomplishing completion of the authorized project at Cattaraugus Creek Harbor, NY.

69. Proponents of a Federal Project at Cattaraugus Creek have been on record for over 30 years requesting flood control and navigation improvements. The creek presently is used for recreational boating. The boating opportunities are limited because littoral drift now restricts the navigation entrance during the summer when creek discharges are insufficient to maintain an adequate navigation depth. The sand bar which forms across the mouth often remains in the winter. Ice builds on the bar, blocking or restricting the creek mouth. This results in damaging floods even under low discharges. The damage to property is more related to the ice jams than to the discharge-frequency relationship normally encountered on a flood control project.

70. The primary improvements desired by local interests are relief from flooding induced by the ice-jamming and enhancement of navigation opportunities by maintaining a navigable depth in the creek mouth. A multiple-purpose plan was devised in the project document and refined in the Phase I General Design Memorandum to achieve the improvements requested. That plan was reviewed in this Phase II study and modified to achieve the same objectives at less cost, despite escalating price levels. The major modifications are:

a. The breakwater layout plan has been reversed to provide a northward in lieu of a southward facing entrance in order to achieve better compatibility with the wave climate and littoral regime.

b. The breakwater type has been changed from cellular and cantilever steel sheet-pile construction to rubblemound construction for cost-saving purposes, for fish-habitat benefits, and for reduction in wave reflections to ameliorate navigation hazards and beach erosion.

c. The navigation project depth has been raised from -6 feet LWD to -3.5 feet LWD in the creek and from -8 feet LWD to -5.5 feet LWD in the entrance channel in order to enhance natural sediment-flushing by river floods and to decrease dredging costs on an annual and, particularly, on a maintenance basis.

d. The levees were eliminated because no further flood protection would be afforded by them since by raising the navigation project depth no increased channel capacity over existing conditions is achieved.

71. As modified, the plan includes constructing breakwaters on either side of the creek mouth both to prevent littoral drift from being transported across the navigation entrance, and to provide a safe navigation channel. This will provide navigation benefits, and by elimination of the bar formation, also provide flood control benefits. The breakwater alignment was designed and tested in a hydraulic model to ensure that sediment transport from the creek to the lake will continue as close to existing conditions as is feasible and still meet the other objectives of the project. The alignment was also tested to ensure that ice would not create a jam in the throat section of the channel.

72. In evaluation, the following points were considered pertinent to the project plan:

a. The plan must preserve to the maximum possible extent the quality of the natural and human environment.

b. The plan must be socially acceptable.

c. The plan must enhance the economic welfare of the local people and add to their security and well-being.

d. The plan must enhance the economic development by increasing the value of the Nation's output of goods and improving National economic efficiency.

e. The plan must fit integrally into an overall plan for water and related land resource management and development for the Buffalo Metropolitan Area Study.

f. The plan must be technically and economically feasible to implement.

73. I have carefully considered the comments of the U. S. Department of the Interior, Northeast Region, regarding archaeological values and the potential for littoral drift interruption and possible shore erosion. As indicated in the Final Environmental Impact Statement (FEIS) for this project, a cultural resources survey of the actual construction sites will be performed prior to project construction. The results of that survey will be included as an addendum to the FEIS. This procedure will allow for any necessary mitigating measures to be accomplished prior to actual construction. In view of the foregoing, I find: that the proposed action, as initially developed in the project document and Phase I Design Memorandum, and with modifications as proposed in this Phase II Design Memorandum, is based on an analysis and evaluation of all practicable alternative courses of action for achieving the needed assurance of increase in recreational benefits and reduction in flood damages; that, wherever adverse effects are found to be involved, they cannot be avoided by following reasonable alternative courses of action which would achieve the Congressionally specified purpose; that, where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other beneficial considerations and, that, on balance, the total public interest should best be served by implementation of the recommendation.

XXI - RECOMMENDATION

74. I recommend that the authorized plan of improvement for small-boat navigation, flood control, and other recreational uses at Cattaraugus Creek Harbor, NY, as outlined in House Document 97, with minor modifications as developed in the Phase I GDM and this Phase II GDM, serve as the basis for preparation of the plans and specifications for this project. However, no further action should be taken on this project until local interests have executed the required assurances of local cooperation to include a commitment to furnishing the non-Federal cash contributions.

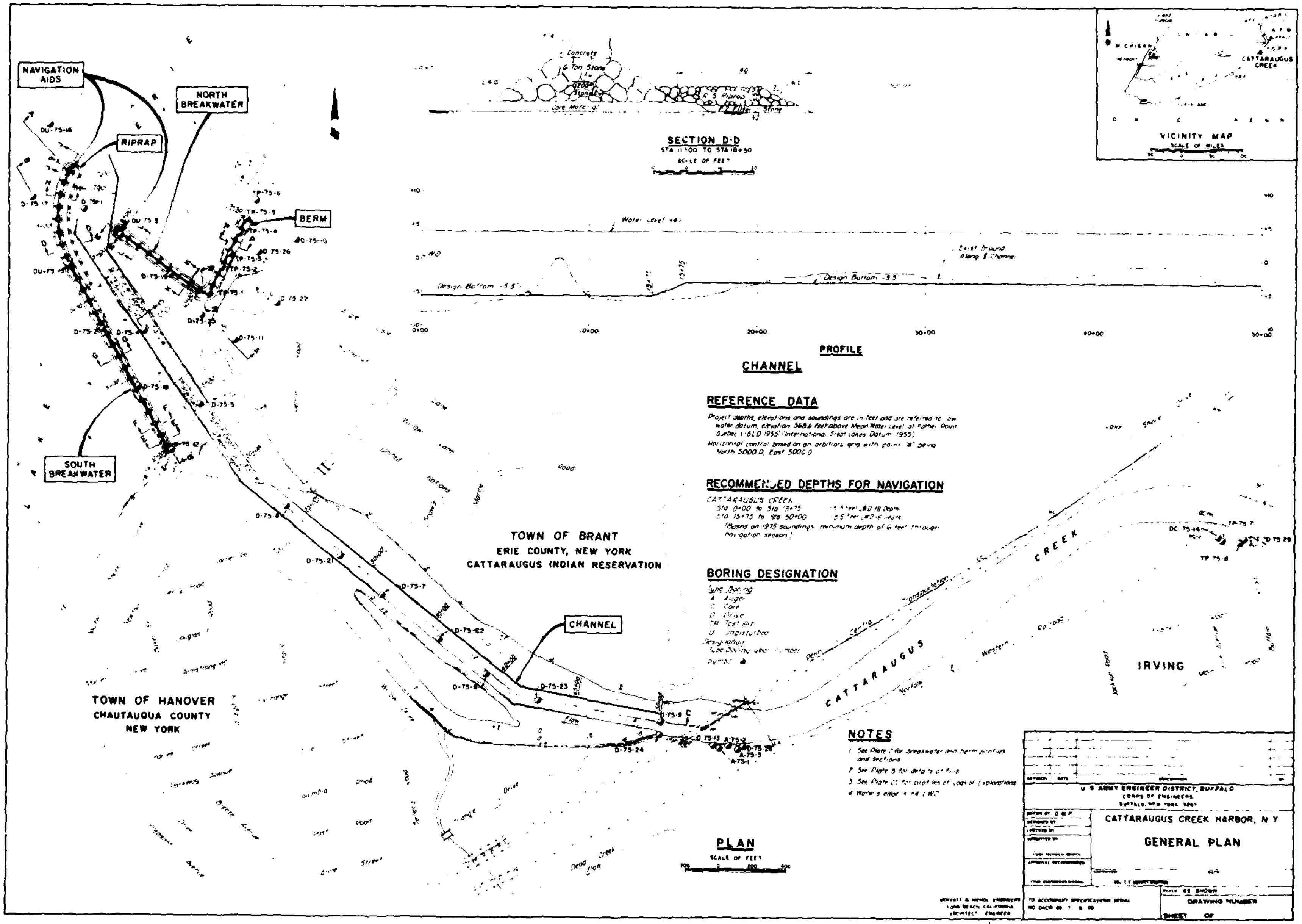

NAVIGATION AIDS
NORTH BREAKWATER
RIPRAP
BERM
SOUTH BREAKWATER
SECTION D-D
STA 11+00 TO STA 18+50
VICINITY MAP
CATTARAUGUS CREEK
PROFILE
CHANNEL
REFERENCE DATA
RECOMMENDED DEPTHS FOR NAVIGATION
BORING DESIGNATION
TOWN OF BRANT
ERIE COUNTY, NEW YORK
CATTARAUGUS INDIAN RESERVATION
TOWN OF HANOVER
CHAUTAUQUA COUNTY
NEW YORK
CHANNEL
CATTARAUGUS CREEK
IRVING
NOTES
PLAN
U S ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
CATTARAUGUS CREEK HARBOR, N Y
GENERAL PLAN
DRAWING NUMBER
PLATE I

PLATE I

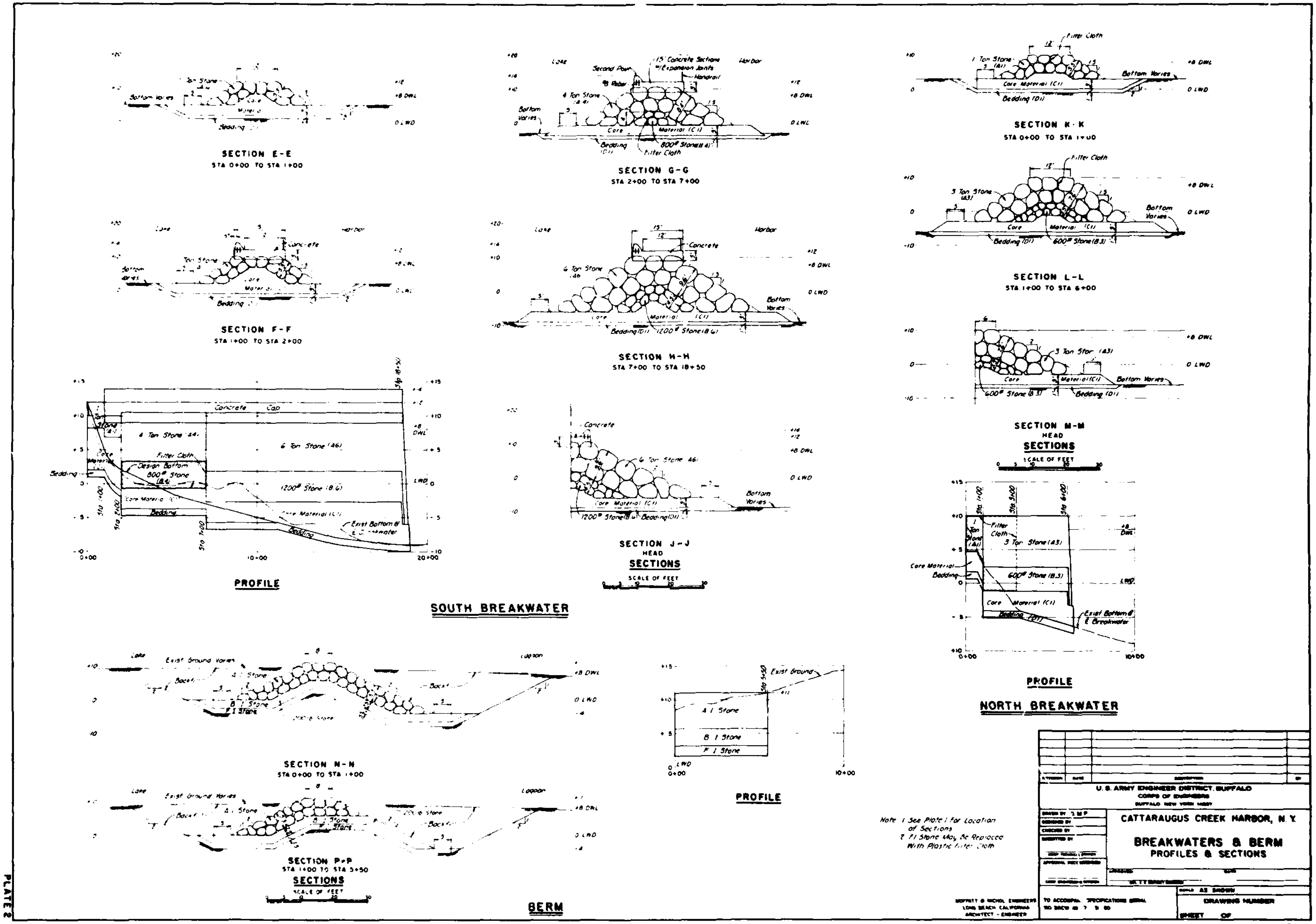
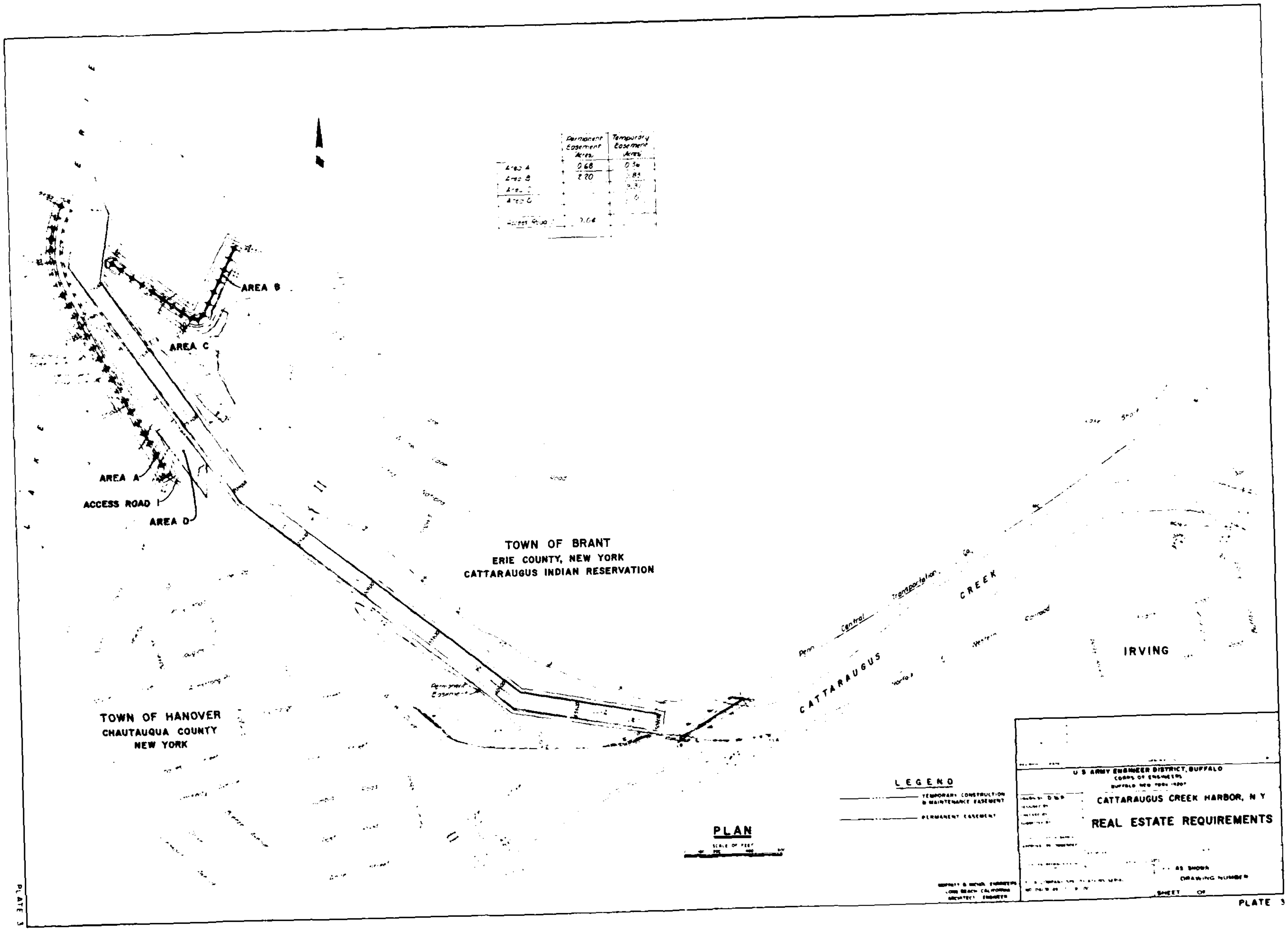

SECTION E-E
STA 0+00 TO STA 1+00
SECTION G-G
STA 2+00 TO STA 7+00
SECTION K-K
STA 0+00 TO STA 1+00
SECTION F-F
STA 1+00 TO STA 2+00
SECTION H-H
STA 7+00 TO STA 18+50
SECTION L-L
STA 1+00 TO STA 6+00
SECTION M-M
HEAD
SECTION J-J
HEAD
SECTIONS
SCALE OF FEET
PROFILE
SOUTH BREAKWATER
NORTH BREAKWATER
SECTION N-N
STA 0+00 TO STA 1+00
SECTION P-P
STA 1+00 TO STA 5+50
BERM
Note 1 See Plate 1 for Location of Sections
2 F1 Stone May Be Replaced With Plastic Filter Cloth
U. S. ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
CATTARAUGUS CREEK HARBOR, N. Y.
BREAKWATERS & BERM
PROFILES & SECTIONS
SCALE AS SHOWN
DRAWING NUMBER
MOFFATT & NICHOL ENGINEERS
LONG BEACH CALIFORNIA
ARCHITECT - ENGINEER

PLATE 2


AREA B
AREA C
AREA A
ACCESS ROAD I
AREA D
TOWN OF BRANT
ERIE COUNTY, NEW YORK
CATTARAUGUS INDIAN RESERVATION
TOWN OF HANOVER
CHAUTAUQUA COUNTY
NEW YORK
CATTARAUGUS CREEK
IRVING
LEGEND
TEMPORARY CONSTRUCTION & MAINTENANCE EASEMENT
PERMANENT EASEMENT
PLAN
U S ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
CATTARAUGUS CREEK HARBOR, N Y
REAL ESTATE REQUIREMENTS
AS SHOWN
DRAWING NUMBER
SHEET OF
PLATE 3

APPENDIX A

HYDROLOGY, HYDRAULICS STUDIES AND FLOOD DAMAGES AND BENEFITS

APPENDIX A

HYDROLOGY, HYDRAULIC STUDIES, AND FLOOD DAMAGES AND BENEFITS

Table of Contents

Table of Contents (Cont'd)

FLOOD CONTROL

A1.00 GENERAL

The Cattaraugus Creek watershed covers an area of 554 square miles in western New York. Cattaraugus Creek is about 70 miles long and flows generally westward into Lake Erie.

A1.01 CLIMATE

In general, the climate for the region containing the project site is temperate, humid-continental with the chief characteristic of rapidly changing weather. The prevailing winds are from the southwest over Lake Erie. Due to this exposure, strong winds are common throughout the year. The lake is a moderating influence on temperature in the lower portion of the Cattaraugus drainage area but, because of the hilly characteristics of the upstream regions, greater temperature extremes occur in areas farther removed from the lake. Precipitation amounts tend to be localized and subject to orographic influence because of relatively steep topography.

A1.02 CLIMATOLOGICAL STATIONS

There are only two climatological stations within the Cattaraugus Creek watershed proper; at Gowanda State Hospital (Lat. 42^{o} 32' and Long. 78^{o} 25') and Arcade (Lat. 42^{o} 32' and Long. 78^{o} 25'). However, there are 13 climatological stations located outside of the area but in the immediate vicinity of the watershed. Plate A1 shows the location of these stations and other stations adjacent to the basin.

A1.03 PRECIPITATION

The monthly and annual precipitation for the two climatological stations located in the Cattaraugus Creek watershed are listed in Table A1. The monthly averages over the watershed vary from a maximum of 4.04 inches in June to a minimum of 2.24 inches in February. The average annual precipitation computed for the two stations is 38.29 inches.

Table A1 - Average Monthly and Annual Precipitation in Inches

Station	Yrs of record used in averages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Arcade[1]	22	2.92	2.30	2.70	3.51	3.27	4.04	3.43	3.55	3.76	2.94	3.97	3.61	40.00
Gowanda State Hosp.[1]	22	2.61	2.24	2.62	3.10	2.99	3.44	3.02	3.52	3.50	2.96	3.50	3.08	36.58

[1]Final year in average - 1972.

A1.04 SNOWFALL

Snowfall records of 21 years are available for the Arcade station and are shown in the table below. Arcade, the one station in the Cattaraugus Creek watershed which records snowfall data, has an average annual snowfall of 92.2 inches.

Table A2 - Average Monthly and Annual Snowfall in Inches

Station	Yrs. of snowfall record	Final year in avg.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Arcade	21	1972	22.1	15.6	13.2	2.3	0.1	T	0	T	T	0.7	15.1	23.1	92.2

A1.05 TEMPERATURE

The average annual mean temperature based on the two stations located in the Cattaraugus watershed is 46.4 degrees.

Table A3 - Average Monthly Mean Temperature in Degrees Fahrenheit

Station	Yrs. of temp. record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Arcade[1]	18	18.7	22.2	29.5	44.0	53.9	53.4	66.6	65.1	59.1	49.2	37.8	25.4	44.6
Gowanda State Hosp.[1]	22	24.7	26.0	33.7	46.9	56.5	66.0	70.0	68.3	62.7	52.6	41.0	30.0	48.2

[1]Final year in average - 1972.

A1.06 NOTABLE STORMS

Notable storms that have caused flooding in various portions of the Cattaraugus Creek watershed occurred during the months of March 1942, April 1947, March 1948, February 1953, October 1954, October 1955, March 1956, January 1959, February 1961, March 1963, September 1967, March 1972, June 1972, and February 1976. However, rainfall runoff is not normally the major contributing cause to the damaging floods at the mouth of the creek. Sand bars frequently form across the mouth of the creek. In the late winter and early spring, lake ice, windrowed on shore by lake storms, forms another barrier. These obstacles deny the creek free access to the lake and affect stages near the mouth. The effects of these obstructions are particularly apparent during the spring thaw when ice carried by the high discharges is blocked by the sand bar and lake ice. These ice jams often raise the water to higher levels than would occur naturally from the discharge developed by the combination of rainfall and snow melt. It is this combination of events that has caused the major recorded flood events. The storms of October 1954 and October 1955, September 1967 and June 1972, were among the larger rainfall producing storms but did not result in the higher and more damaging water levels at the mouth because access to the lake was available. Because ice jams and sand bars are contributing factors of varying effect in the major recorded floods, detailed investigations of the coincident rainfalls and runoffs were not considered to be necessary to develop the conclusions of this report.

A1.07 STREAM FLOW RECORDS

Stream flow data for Cattaraugus Creek are available from the records of the United States Geological Survey (U.S.G.S.) stage recording gage at Gowanda, approximately 14 miles upstream from the mouth. Some historical data were also recorded at a former U.S.G.S. gage site at Versailles about 6 miles downstream of the Gowanda site. Two more recording gages were in operation for a short time in the basin near Arcade and Springville. Pertinent data on these gaging stations are given in table A1. The locations of the gaging stations are shown on Plate A1.

A1.08 FLOODS OF RECORD

Damaging floods along Cattaraugus Creek have a reported history dating back 100 years. The resort areas near the mouth of the creek have developed primarily in the last 30 years, so that good information on flood events prior to that time is not available. During the period of the Gowanda gage record, significant flooding occurred at the mouth of the creek in March 1942, June 1944, April 1947, February 1953, October 1955, March 1956, January 1957, January 1959, February 1961, March 1963, March 1972, June 1972, and February 1976, the maximum flood of record. Although each of the flood events was coincident with a moderate or high discharge in the creek, most of the higher stages were aggravated by ice jams near the mouth.

Table A4 - Stage Gages on Cattaraugus Creek and Tributary

	Gage Location							
Locality	Latitude	Longitude	Type	Drainage area sq. mi.	Period of record	Maximum discharge cfs	Record stage, feet	Date
Versailles	42°31'25"	78°59'20"	Chain	464	1910-1923	25,000	12.3	25 March 1913
Gowanda	42°27'50"	78°56'10"	Recording	428	1940-(2)	34,600	13.73	7 March 1956
Arcade	42°32'14"	78°27'28"	Recording	78.4	1963-1968	9,730	9.84	28 September 1967
Springville[1]	42°28'21"	78°39'54"	Recording	29.4	1961-1968	3,910	8.50	28 September 1967

1 Located on Buttermilk Creek

2 Present

Since there is no stage recording gage near the area under study, the peak stages for the more recent events were estimated from highwater marks and comparative information obtained in interviews. Flooding in the vicinity of the mouth of Cattaraugus Creek is aggravated by the formation of a sand bar near the mouth of the creek which partially or totally blocks the creek outlet and provides a natural barrier encouraging the formation of ice jams at that point. The severity of flooding at the mouth is thus contingent upon existence of an ice jam blocking the mouth of the creek at the time of a moderate or high stream discharge.

For comparative purposes, four of these profiles, the February 1976, March 1963, February 1961, and March 1972, are shown on plates A2 & A3 with the 22,000 cfs and 50,000 cfs profiles, respectively.

A1.09 PEAK FLOWS

Peak flows at the mouth of the creek for the floods of record were estimated using a discharge-area relationship based on the indicated discharge at the Gowanda gage, related peak discharges on other gaged streams in western New York and on an actual discharge measurement made at the U.S. Route 20 bridge over Cattaraugus Creek during a peak flow period on 25 April 1961. On the basis of comparison of the ratios of discharge obtained by the various methods it was estimated that the ratio of peak discharge at the mouth to that passing the Gowanda gage would average 1.29 for evenly distributed storms.

A1.10 RATING CURVE FOR DAMAGE REACHES UNDER EXISTING CONDITIONS

Post flood damage interviews after the February 1961 flood and the March 1963 resulted in forming two damage reaches for the area, one on each side of the creek. The damage analysis for the area was completely revised and updated after the March 1972 flood. A single index point was selected for the two reaches.

Because most flooding at the mouth of Cattaraugus Creek results from flow conditions influenced by ice jams and sand bar build up, the traditional stage-discharge relationship does not usually apply. However, in order to provide a comparison with the estimated stage-discharge curves for improved conditions, theoretical curves were developed for natural conditions assuming free flow conditions into Lake Erie. Backwater analysis of various flows yielded the existing stage-discharge curve shown on plate A4. The shape of the lower portion of the curve is dependent on Lake Erie stage and conditions at the mouth of the creek at the time of discharge.

A1.11 RATING CURVE FOR DAMAGE REACHES UNDER IMPROVED CONDITIONS

A stage-discharge curve was also developed for improved conditions and is used to show the amount of stage reduction produced by the channel capacity of the creek due to the construction of the proposed improvements. It is also shown on plate A4.

The improved channel sections were developed using navigation criteria. The effect of the considered improvement on flood levels was determined to ascertain the flood benefits derived from the improvement. In developing the curve for improved channel conditions it was assumed that the breakwaters at the mouth of the creek and continued channel maintenance would eliminate the conditions which, in the past, have caused the sand bars and ice jams to be formed. However, even under improved conditions, the stage-discharge relationship at the index point will be affected by high lake stages. In order to insure that the improvement would prevent flood damage even under adverse lake stages, an investigation was made of the effect on stages at the index point of a high Lake Erie stage of relatively frequent occurrence. Similar records for the United States Lake Survey gages at Buffalo, New York and Erie, Pennsylvania were examined to determine the approximate difference in lake elevation during storm periods between Buffalo and the mouth of Cattaraugus Creek. An investigation was also made of past flood occurrences and high coincident lake stages. An average lake elevation of 571.1 I.G.L.D. (1955) was used as the starting elevation for backwater computations for improved conditions.

A1.12 FLOOD FREQUENCIES UNDER EXISTING CONDITIONS

For the reasons stated in the preceding paragraphs, there is very little relationship during a given flood between the maximum stage and the discharge. In order to determine the damage-frequency relationship for existing conditions, a study was made of the stage-frequency relationship in the damage area. No actual stage records are available for Cattaraugus Creek in the vicinity of the mouth. During damage interviews, it was determined that the known flood history covered a period of approximately 33 years and that damaging stages were exceeded about every other year. Although actual stages could not be obtained for all of the flood events, highwater marks were established for most of the major occurrences. Sufficient data were gathered on the stages of several other events from flood pictures, newspaper accounts and personal interviews. A stage-frequency curve was developed from this data and is shown on plate A5.

A1.13 DISCHARGE FREQUENCIES

No actual records of discharge are available for Cattaraugus Creek in the vicinity of the mouth. Because of the lack of those records, discharge records from Cattaraugus Creek at Gowanda, NY, were included with those from Buffalo Creek at Gardenville, NY, Cayuga Creek at Lancaster, NY, and Cazenovia Creek at Ebenezer, NY, to form the basis for a regionalized discharge-frequency study. These sites were selected because their hydrologic characteristics are representative of the study area. The resultant discharge-frequency curve is shown on plate A6.

A1.14 FLOOD FREQUENCIES UNDER IMPROVED CONDITIONS

The discharge-frequency relationship developed in paragraph A1.13 would not be affected by the considered improvement. The improvement would be designed to eliminate the conditions which now cause sand bars and ice jams. Under improved conditions the stage-discharge relationship at the index point would be affected only by lake stages. The improved stage-frequency curves were obtained from the stage-discharge and discharge-frequency curves and are shown on plate A5.

A1.15 DESIGN DISCHARGE FOR IMPROVEMENT

The improved channel section was designed for navigation criteria and has the same channel capacity as the present channel with the elimination of conditions which now cause sand bars and ice jams. The capacity of the present channel is 22,000 cfs. Damaging stages would be exceeded on the average of about once in 3 years. A higher level of flood protection could not be economically justified.

The average channel velocities would be lower under improved conditions than under natural conditions but would still average over six feet per second. There is a slight increase in velocity of 0.3 feet per second immediately downstream of the Penn Central Railroad as shown in the velocity profile on Plates A2 and A3 for various discharges.

The Hydraulic Model Study Investigation (See Appendix G) determined the optimum configuration and lengths of the breakwaters and opening between them for wave protection and prevention of shoaling. Although construction of the breakwaters would raise the water surface profile slightly above existing conditions at the mouth of Cattaraugus Creek this is parially compensated for by the proposed channel improvements. But additional compensating excavation on the south side of the creek bank at the mouth will be performed to return the creek profile back to natural conditions and overbank flooding will occur at a discharge of 22,000 cfs.

Therefore, change in alignment or lengths of the breakwaters to lower the water surface profile at the creek mouth is not necessary, and would only have a detrimental effect on navigation or shoaling prevention.

A.1.16 LEVEE DESIGN

Under improved conditions in the Phase I report, bank full capacity was increased to 30,000 cfs. To obtain flood benefits from the increased channel capacity, it was necessary to protect the land adjacent to the channel improvement from overland flooding originating upstream of the proposed improvement. It was determined that this overland flooding originated in two locations, between the Penn Central Railroad and between the Norfolk & Western Railroad and Buffalo Road. To prevent this overland flooding, two levees were designed to contain 30,000 cfs in the channel.

In the Phase II design, the channel capacity is 22,000 cfs which is the same as existing conditions and no additional benefit is gained from these levees. For this reason, the levees are not required in this design.

A1.17 ICE JAM CONSIDERATIONS

The flood control benefits derived from the considered plan of improvement are obtained primarily by effectively dealing with the ice jam potential discussed in previous paragraphs. Maintenance of the considered channel will provide the capacity necessary for the exit of ice flows. The design of the breakwater configuration was optimized for efficiency from results obtained from model test efforts being conducted at the Waterways Experiment Station (WES), in Vicksburg, Mississippi, precluding the threat of sand bar build up at the mouth of the creek. When the ice cover of Lake Erie exists, the considered improvements will discharge the ice flows of Cattaraugus Creek under the lake ice. This type of movement has been observed during the natural breakup of ice jams and also after dynamiting efforts were successful in dislodging ice jams at the mouth in the vicinity of the sand bar. The breakwaters should also preclude the formation of windrowed ice against the channel mouth. The width and depth of the maintained channel, without the obstruction from the sand bar and windrowed ice will permit the discharge of ice flows.

FLOOD DAMAGES AND BENEFITS

A2.00 GENERAL

Substantial flood damage occurs frequently at the mouth of Cattaraugus Creek. Some of the notable recent occurrences are February 1953, March 1956, January 1959, February 1961, March 1963, February 1965, February 1965, February 1966, September 1967, January 1968, March 1972 and February 1976. All of these occurrences, except that of September 1967, were caused by ice jams. Historical research indicates that the frequent regularity of flooding has always been the case.

A comprehensive damage survey conducted by the Corps of Engineers after the February 1961 flood was updated after the March 1963 flood and then completely revised after the March 1972 flood. The resultant data was used to determine average annual flood losses for existing and improved channel conditions.

A2.01 AREAS SUBJECT TO FLOODING

The area most often subjected to flooding in the Cattaraugus Creek watershed is at the mouth. Flooding occurs on both banks of the creek from a point below the Penn Central Railroad embankment to the shores of Lake Erie. All of the flooded area on the northerly bank lies within the Cattaraugus Indian Reservation and is located in the county of Erie, Town of Brant. On the southerly bank, the community of Sunset Bay lies in the flooded area. The southerly bank is in the County of Chautauqua, Town of Hanover. The creek itself is the county boundary line. Approximately the same areas are flooded in each major occurrence, although in February 1961, March 1963, March 1972, and February 1976, areas in the community of Irving were also affected. Although flood damage does occur in the upper watershed areas, damage studies have been limited to the flooded area shown on plate A7. Limits are shown for the February 1961 and March 1963 floods.

A2.02 CHARACTER OF FLOODED AREA

The areas subjected to recurrent flooding consist of summer residences, year-round residences, marinas and other commercial establishments. The commercial establishments generally serve a seasonal clientele and therefore maintain only minimum stocks at the time when flooding normally occurs. There are three marinas in the area which have docking facilities on the creek within the flooded areas. They are located on both sides of the creek. In the past, no known deaths have been caused directly by flood waters but during the major floods, permanent residents have had to evacuate their homes by boat. Most of the flood damage is the result of first floor flooding of residences and commercial establishments.

Many of the roads in the affected areas are inundated at the time of flooding and repair work must be made upon the return of normal water conditions. The area on the north bank provides its own water and gas while being commercially served with electricity while the area on the south bank is also served by water supply and gas systems. The entire flooded area uses septic tanks for sewage disposal

A2.03 DAMAGE REACHES

The limits of the flood damage reaches and the common index point for the area are shown on plate A7. The damage reaches were selected to include, as much as possible, similar types of property. Therefore, reach 1, which is on the southerly bank of the creek, includes privately-owned residences and lots and reach 2 on the northerly bank includes privately-owned cottages on leased property in the Cattaraugus Indian Reservation. The single index point was located approximately at the mid-point of the damage area and is representative of stages in both damage reaches.

A2.04 STAGE-DAMAGE CURVES

Using the March 1972 flood as a basis, damages were estimated using data obtained from actual interviews and from depth-percent damage data used in the Flood Insurance Study for Hanover Township in 1971. A range of flood elevations both higher and lower than the March 1972 flood were considered in the analysis and the resultant stage damage curves shown on plates A8 and A9 were derived.

A2.05 AVERAGE ANNUAL BENEFITS

Under the considered plan of improvement, certain flood control benefits would be derived from the elimination of ice jamming conditions at the mouth of the creek resulting from the proposed improvements. These benefits have been computed by subtracting the estimated average annual residual damages with the improvements in place, from the estimated average annual damages under existing conditions. Table A5 lists the estimated average annual benefits provided by the considered improvements, based on June 1972 price levels and conditions of development.

Table A5 - Estimated Average Annual Flood Control Benefits

Reach	Damages from Ice and Free Flow June 1972	Damage from free Flow June 1972	Average Annual Benefits June 1972	Average Annual Benefits Sept. 1975 (1)
	$	$	$	$
1	54,120	18,970	35,240	44,760
2	48,540	13,450	35,090	44,560
Total	102,750	32,420	70,330	89,320

(1) Building Cost Index $\frac{\text{Sept. 1975}}{\text{June 1972}} = \frac{1,332.14}{1,047.00} = 1.27$

A2.06 DAMAGE CAUSED BY THE FEBRUARY 1976 STORM

An ice jam at the mouth on 17 February 1976 of Cattaraugus Creek caused widespread flooding in the Sunset Bay area in the towns of Hanover and Brant. Flood conditions exceeded the March 1963 highwater occurrence, the previous flood of record, by 7 inches. The return period for this flood is estimated at 60 years based on the stage-frequency curve shown on plate A5. Based on the stage-damage curves shown on plates A8 and A9, the damage for the 1976 flood is estimated to be $850,000 based on June 1972 price levels and conditions of development. The damages for this event based on 1976 price levels is estimated at $1,100,000.

The U. S. Geological Survey provisional discharge at the Gowanda gage location is estimated at 19,000 cfs. The peak discharge estimated at the mouth, as discussed in paragraph A1.09, is 24,500 cfs. This discharge based on a discharge-frequency analysis has a return period of only 3 years (see plate A6). The estimated damage, based on free flow conditions can be considered zero. Therefore, under the considered plan of improvement, benefits for this flood event of $1,100,000 could be realized.

A post flood report will be made by this office to fully document this flood of record on Cattaraugus Creek at the mouth. This report will be completed by 1 June 1976.

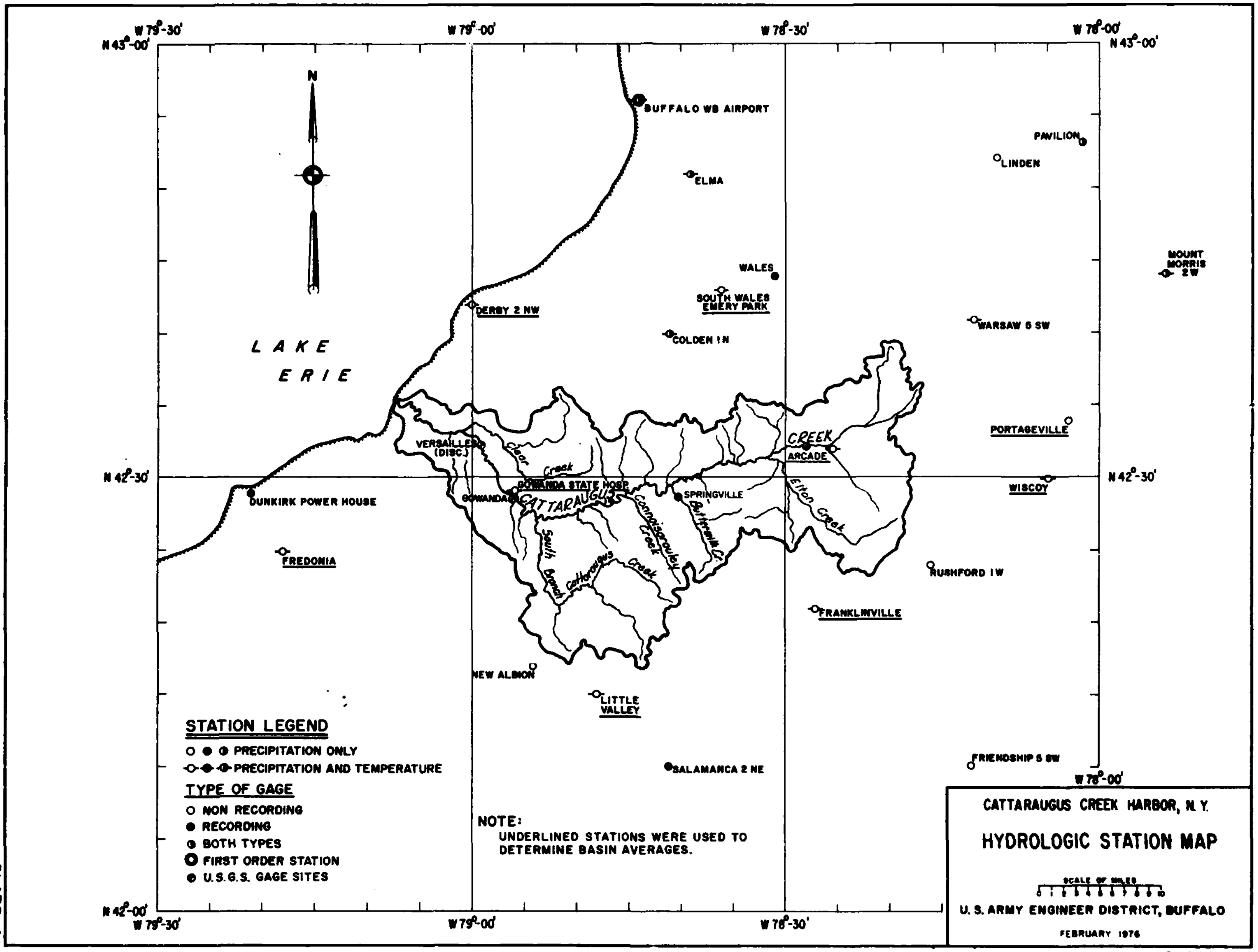
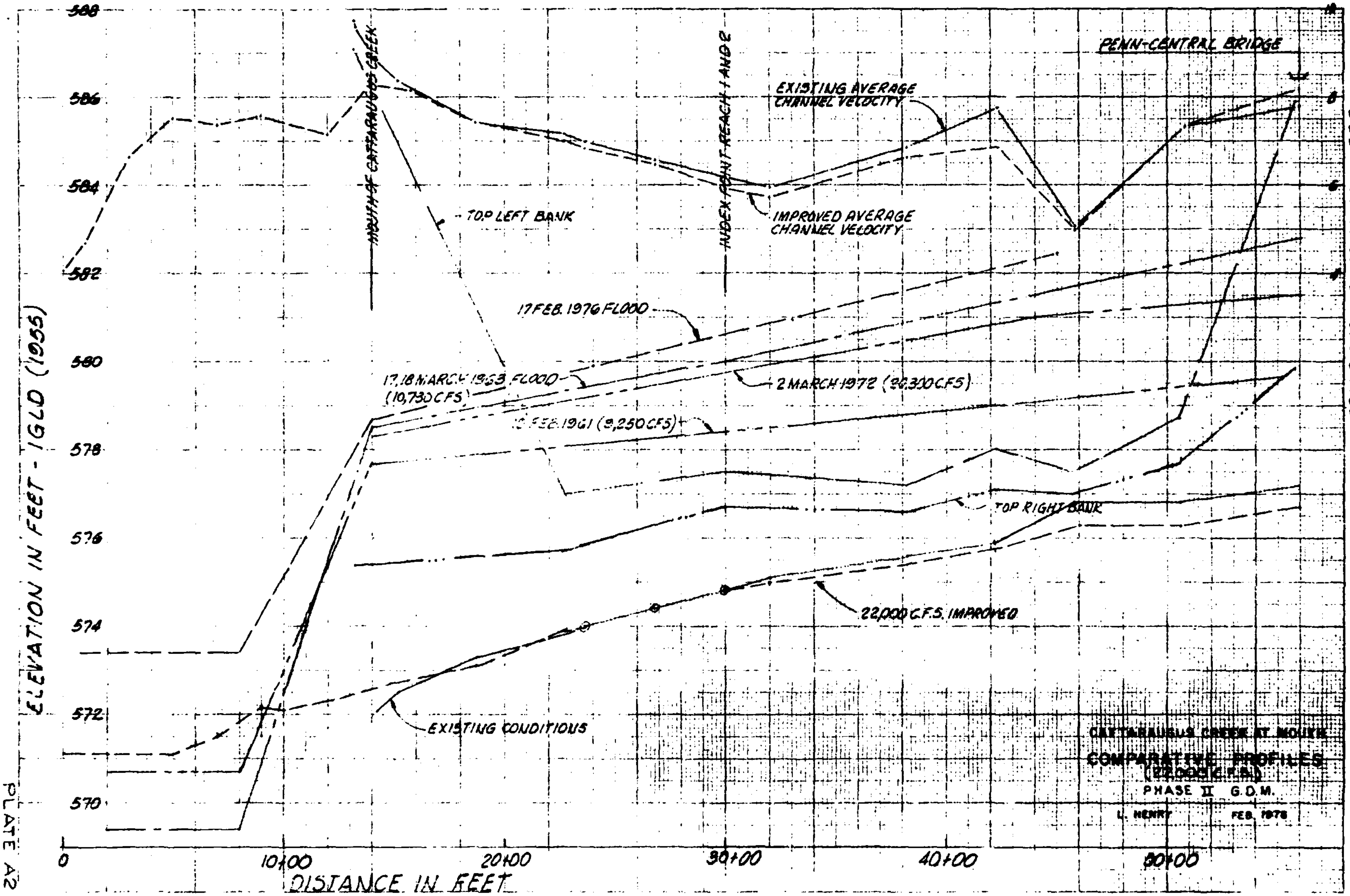


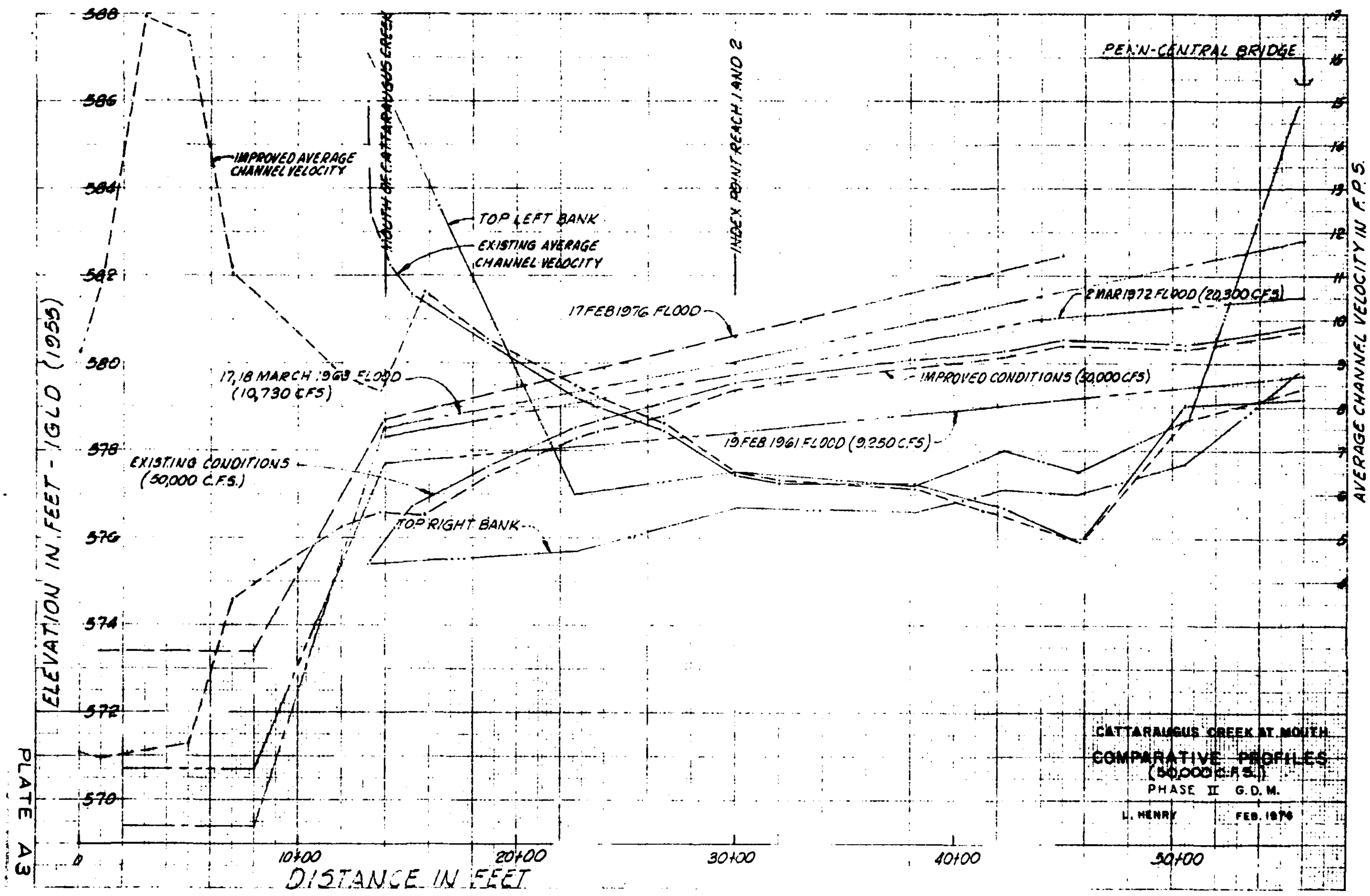
PLATE A1

PLATE A1



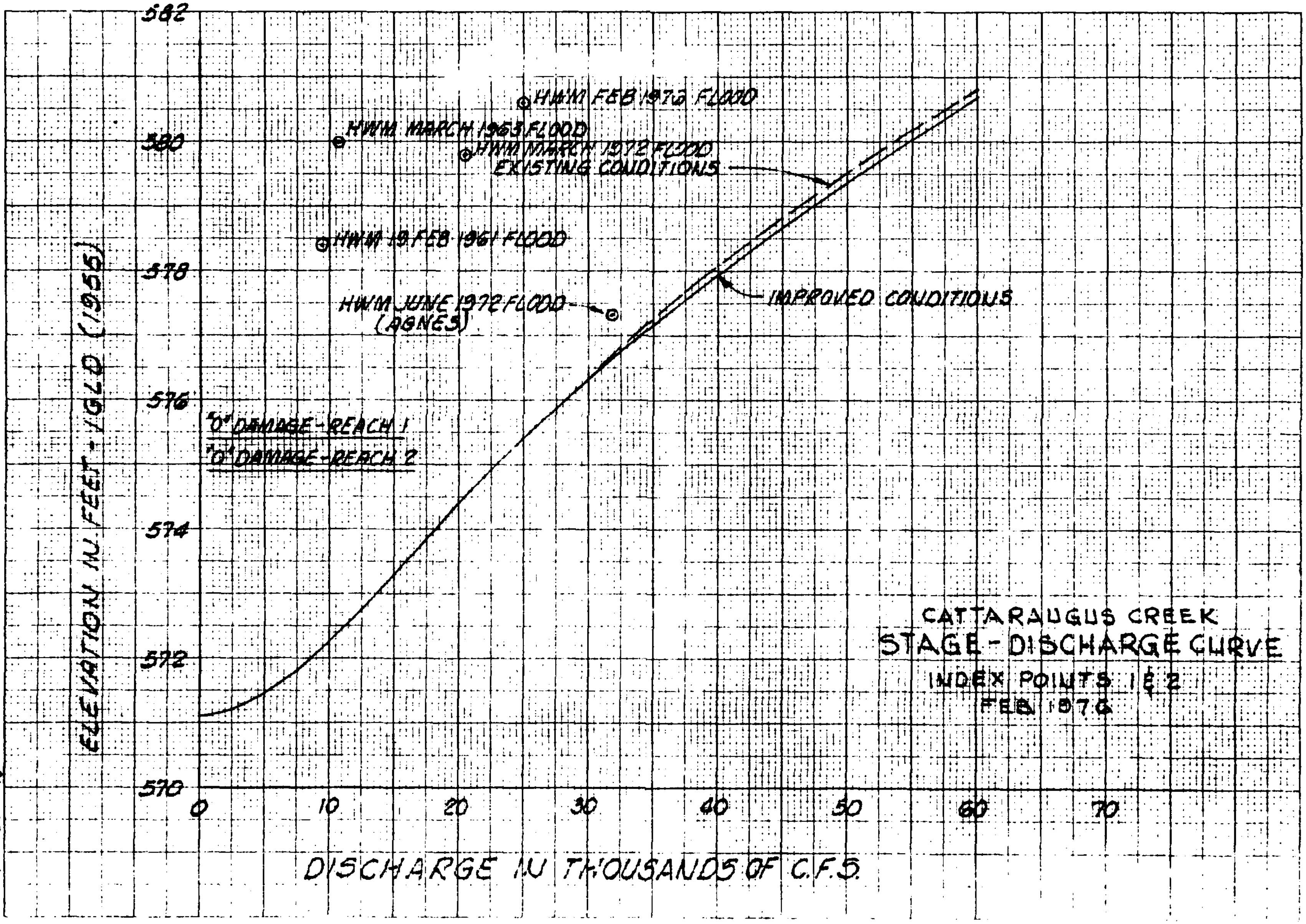
PENN-CENTRAL BRIDGE
EXISTING AVERAGE CHANNEL VELOCITY
IMPROVED AVERAGE CHANNEL VELOCITY
MOUTH OF CATTARAUGUS CREEK
INDEX POINT REACH 1 AND 2
TOP LEFT BANK
TOP RIGHT BANK
17 FEB. 1976 FLOOD
17,18 MARCH 1963 FLOOD (10,730 CFS)
2 MARCH 1972 (20,300 CFS)
FEB. 1961 (9,250 CFS)
22,000 C.F.S. IMPROVED
EXISTING CONDITIONS
ELEVATION IN FEET - IGLD (1955)
AVERAGE CHANNEL VELOCITY IN F.P.S.
DISTANCE IN FEET
0
10+00
20+00
30+00
40+00
50+00
570
572
574
576
578
580
582
584
586
588
CATTARAUGUS CREEK AT MOUTH
COMPARATIVE PROFILES
(22,000 C.F.S.)
PHASE II G.D.M.
L. HENRY
FEB. 1978

PLATE A2



CATTARAUGUS CREEK AT MOUTH
COMPARATIVE PROFILES
(50,000 C.F.S.)
PHASE II G.D.M.
L. HENRY
FEB. 1976
ELEVATION IN FEET - IGLD (1955)
AVERAGE CHANNEL VELOCITY IN F.P.S.
DISTANCE IN FEET
PENN-CENTRAL BRIDGE
MOUTH OF CATTARAUGUS CREEK
INDEX POINT REACH 1 AND 2
IMPROVED AVERAGE CHANNEL VELOCITY
TOP LEFT BANK
EXISTING AVERAGE CHANNEL VELOCITY
17 FEB 1976 FLOOD
2 MAR 1972 FLOOD (20,300 CFS)
IMPROVED CONDITIONS (50,000 CFS)
17,18 MARCH 1963 FLOOD (10,730 CFS)
19 FEB 1961 FLOOD (9,250 CFS)
EXISTING CONDITIONS (50,000 C.F.S.)
TOP RIGHT BANK

PLATE A3


CATTARAUGUS CREEK
STAGE - DISCHARGE CURVE
INDEX POINTS 1 & 2
FEB 1976
ELEVATION IN FEET - IGLD (1955)
DISCHARGE IN THOUSANDS OF C.F.S.
582
580
578
576
574
572
570
0
10
20
30
40
50
60
70
HWM FEB 1976 FLOOD
HWM MARCH 1963 FLOOD
HWM MARCH 1972 FLOOD
EXISTING CONDITIONS
HWM 19 FEB 1961 FLOOD
IMPROVED CONDITIONS
HWM JUNE 1972 FLOOD
(AGNES)
"0" DAMAGE - REACH 1
"0" DAMAGE - REACH 2

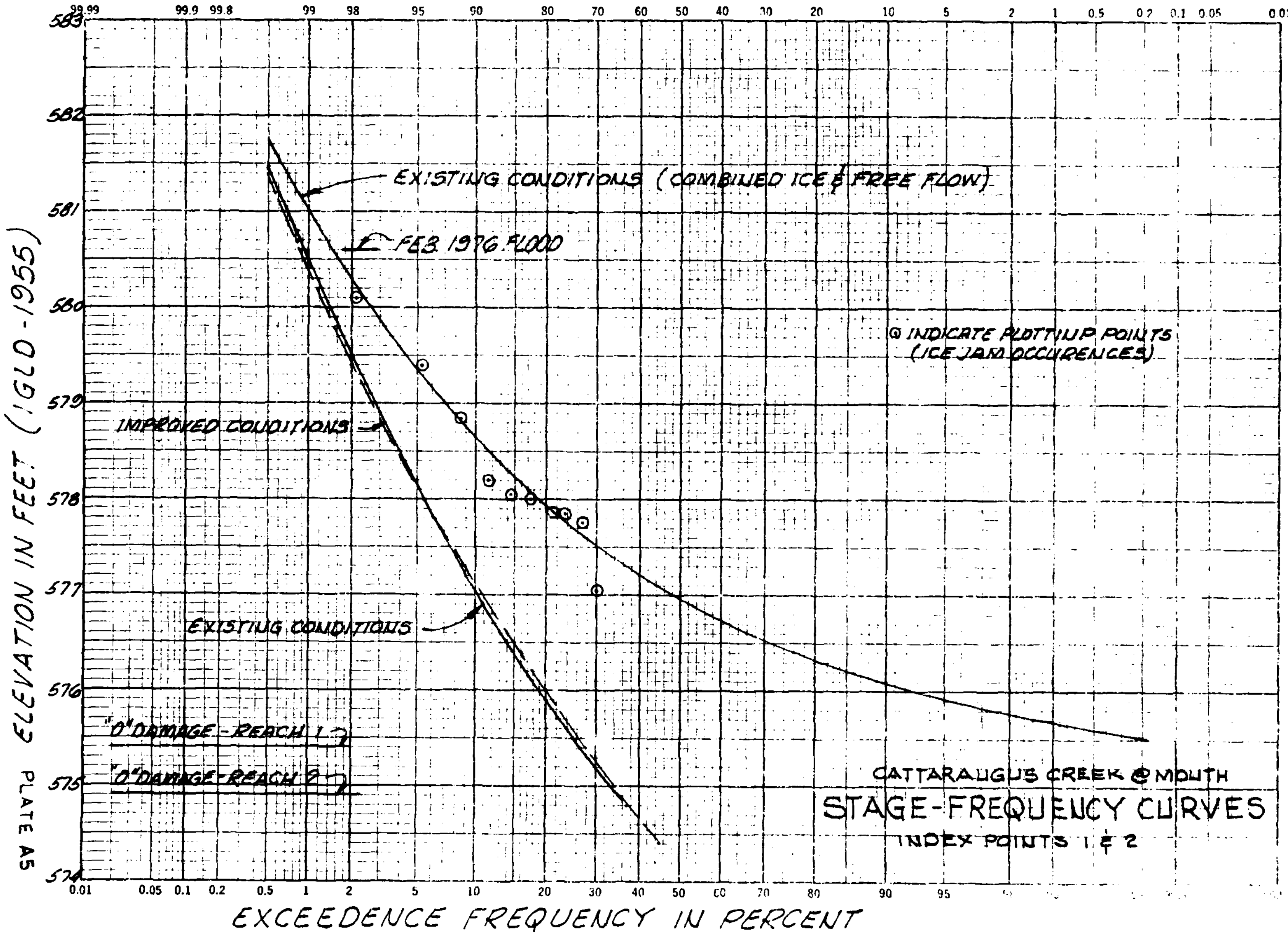
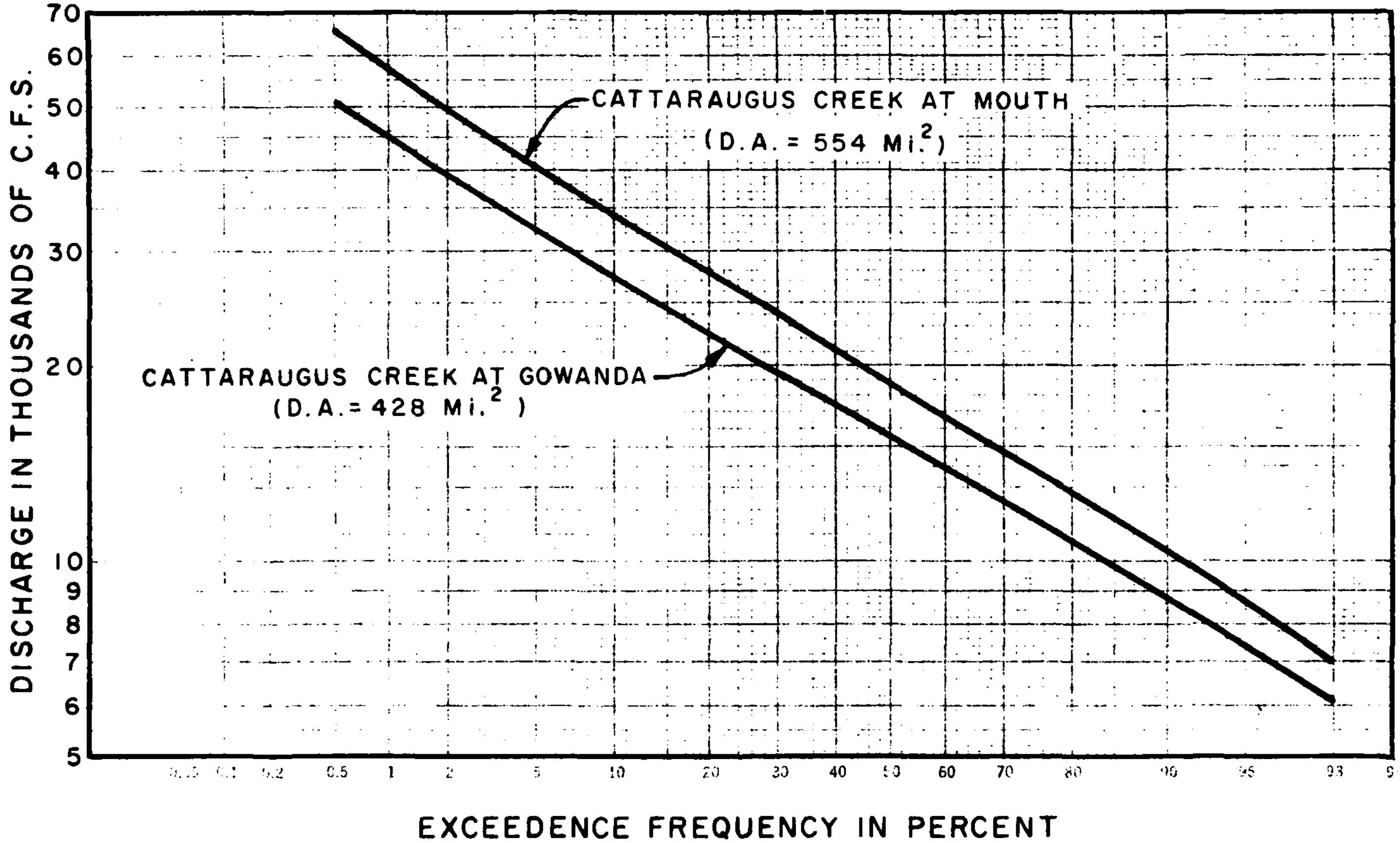

EXISTING CONDITIONS (COMBINED ICE & FREE FLOW)
FEB 1976 FLOOD
⊙ INDICATE PLOTTING POINTS (ICE JAM OCCURENCES)
IMPROVED CONDITIONS
EXISTING CONDITIONS
"0" DAMAGE - REACH 1
"0" DAMAGE - REACH 2
ELEVATION IN FEET (IGLD-1955)
EXCEEDENCE FREQUENCY IN PERCENT
CATTARAUGUS CREEK @ MOUTH
STAGE-FREQUENCY CURVES
INDEX POINTS 1 & 2

PLATE A5

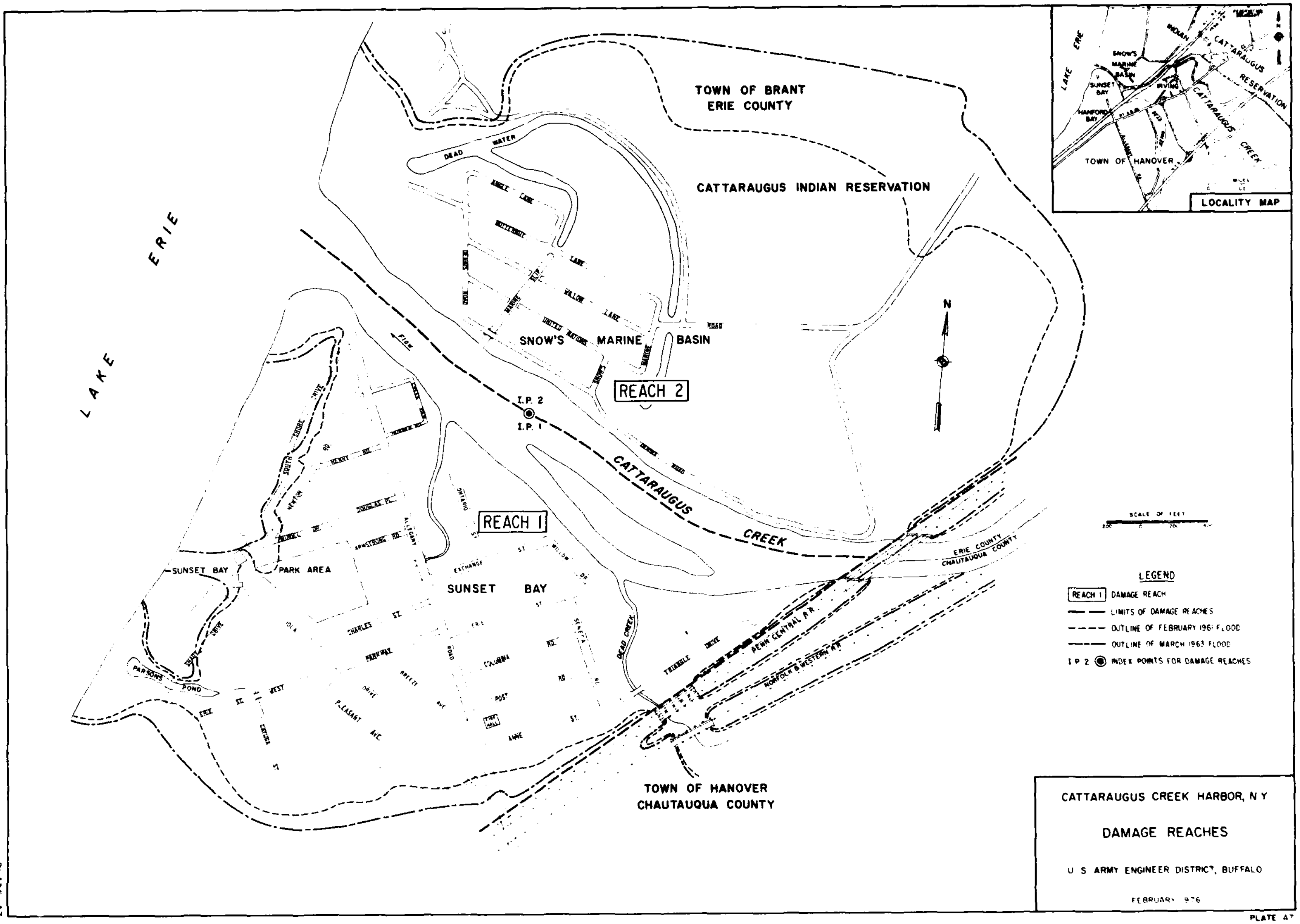


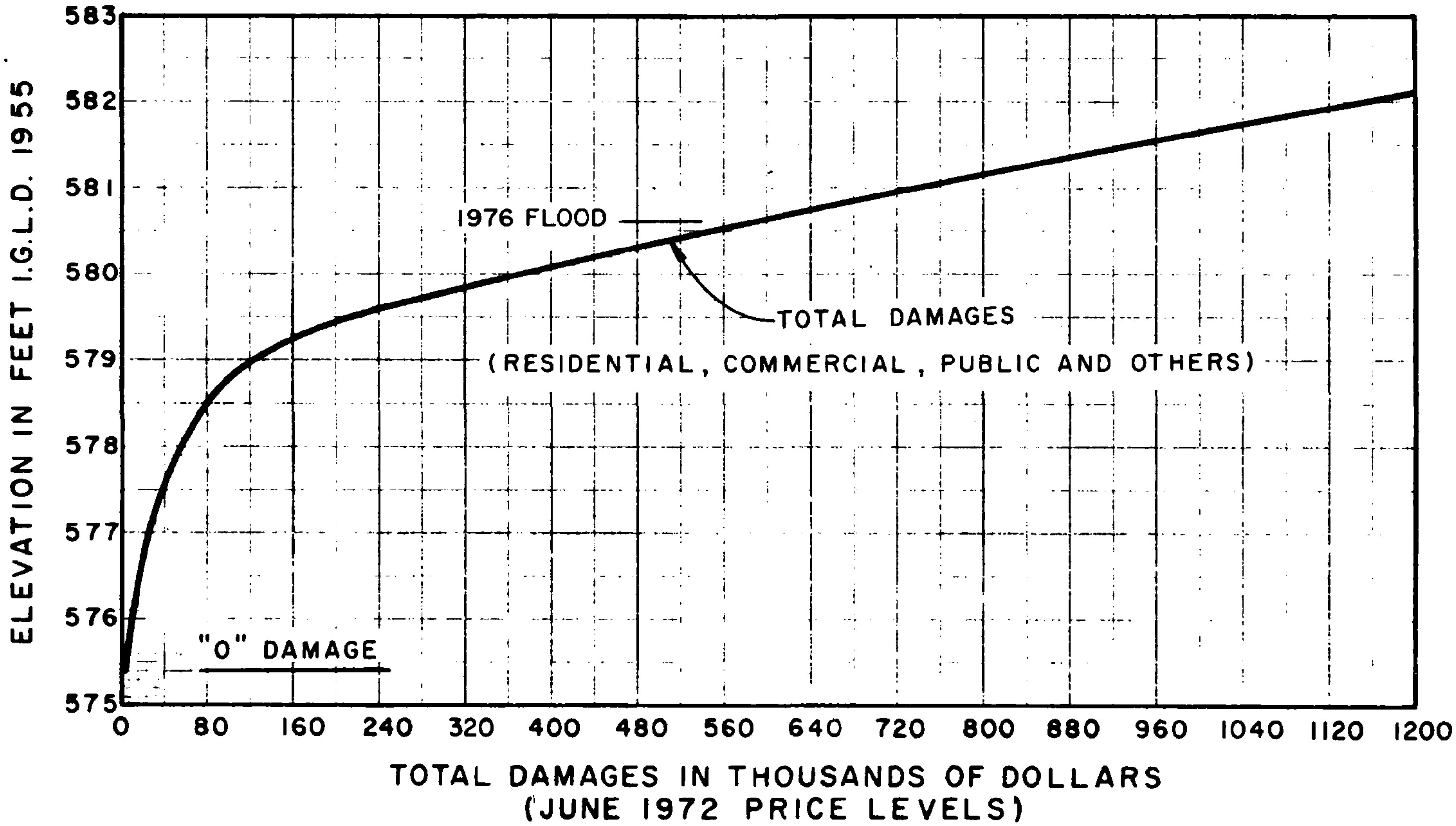
CATTARAUGUS CREEK HARBOR, N.Y.

DISCHARGE - FREQUENCY CURVES

U.S. ARMY ENGINEER DISTRICT, BUFFALO

FEBRUARY 1976

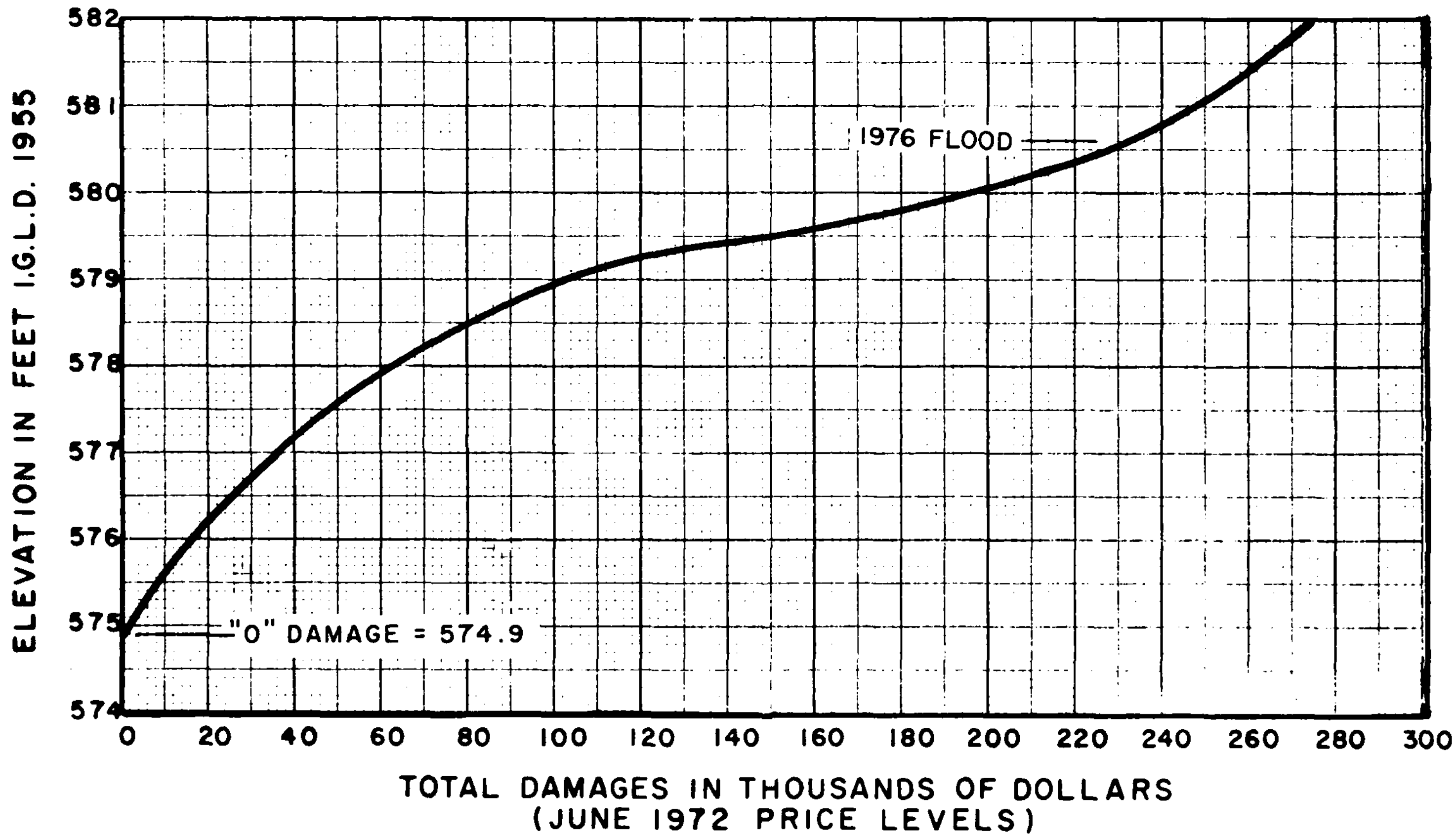

TOWN OF BRANT
ERIE COUNTY
CATTARAUGUS INDIAN RESERVATION
LAKE ERIE
SNOW'S MARINE BASIN
REACH 2
REACH 1
I.P. 2
I.P. 1
CATTARAUGUS CREEK
SUNSET BAY
PARK AREA
DEAD CREEK
PENN CENTRAL R.R.
NORFOLK & WESTERN R.R.
ERIE COUNTY
CHAUTAUQUA COUNTY
TOWN OF HANOVER
CHAUTAUQUA COUNTY
N
LOCALITY MAP
TOWN OF HANOVER
LEGEND
REACH 1 DAMAGE REACH
LIMITS OF DAMAGE REACHES
OUTLINE OF FEBRUARY 1961 FLOOD
OUTLINE OF MARCH 1963 FLOOD
I P 2 INDEX POINTS FOR DAMAGE REACHES
CATTARAUGUS CREEK HARBOR, N Y
DAMAGE REACHES
U S ARMY ENGINEER DISTRICT, BUFFALO
FEBRUARY 1976
PLATE A7



CATTARAUGUS CREEK HARBOR, N.Y.

SUNSET BAY, TOWN OF HANOVER
STAGE - DAMAGE CURVE
INDEX POINT I - REACH I

U.S. ARMY ENGINEER DISTRICT, BUFFALO
FEBRUARY 1976



CATTARAUGUS CREEK HARBOR, N.Y.

SNOWS MARINE-INDIAN RESERVATION
STAGE - DAMAGE CURVE
INDEX POINT 2 - REACH 2

U.S. ARMY ENGINEER DISTRICT, BUFFALO
FEBRUARY 1976

APPENDIX B

IMPACT ON LITTORAL DRIFT

APPENDIX B
IMPACT ON LITTORAL DRIFT
FOR
CATTARAUGUS CREEK HARBOR,
NEW YORK

CONTENTS

CONTENTS
(Continued)

LIST OF TABLES

CONTENTS
(Continued)

LIST OF TABLES
(Continued)

LIST OF FIGURES

IMPACT OF CREEK DREDGING

GENERAL

B1. The purpose of this section is to determine the impact of the channel dredging and harbor improvements on the sediment transport in Cattaraugus Creek. The sediment transport in Cattaraugus Creek is described in detail in Appendix F. Appendix F was based on the plan proposed in the Phase I General Design Memorandum. Cattaraugus Creek is the primary source of littoral drift to the Cattaraugus embayment beaches. Dredging a channel in the creek will create a sediment trap which will decrease the rate at which sediment is delivered into the lake. The distribution of grain sizes transported will also be altered. The breakwater structures will discharge the sediment load into the lake 800 feet further offshore at a depth of -8 feet LWD. Wave and water circulation patterns will be altered by the presence of the breakwater structures and, therefore, will influence the manner in which sediment is transported onto the beaches. The impact of the improvements on sediment transport must be defined in order to estimate maintenance requirements. Maintenance dredging would be required to maintain a navigation channel, remove shoals, and nourish the adjacent beaches.

PERTINENT DATA

B2. The Cattaraugus watershed covers an area of 554 square miles. The discharge-frequency curve for Cattaraugus Creek in Figure B1 indicates a 30,000 cfs discharge recurs once every 6 years, and a 40,000 cfs discharge recurs once every 20 years. Cattaraugus Creek passes through terrain comprising shale, siltstone, and sandstone. The gravel bed of the stream comprises approximately 80 percent siltstone and sandstone, 10 to 15 percent crystalline rock, and a few percent dark shale fragments. The lower 3/4-mile of the creek, downstream of the Penn Central Railroad bridge, has had a relatively stable alignment compared to the meandering channel in the upper reaches. The creek bed comprises a thin layer of fine sand and silt overlying a gravel bed. The fine sand and silt is probably a temporary veneer reflecting the deposits of a recently low-discharge period. This material scours during a relatively moderate discharge

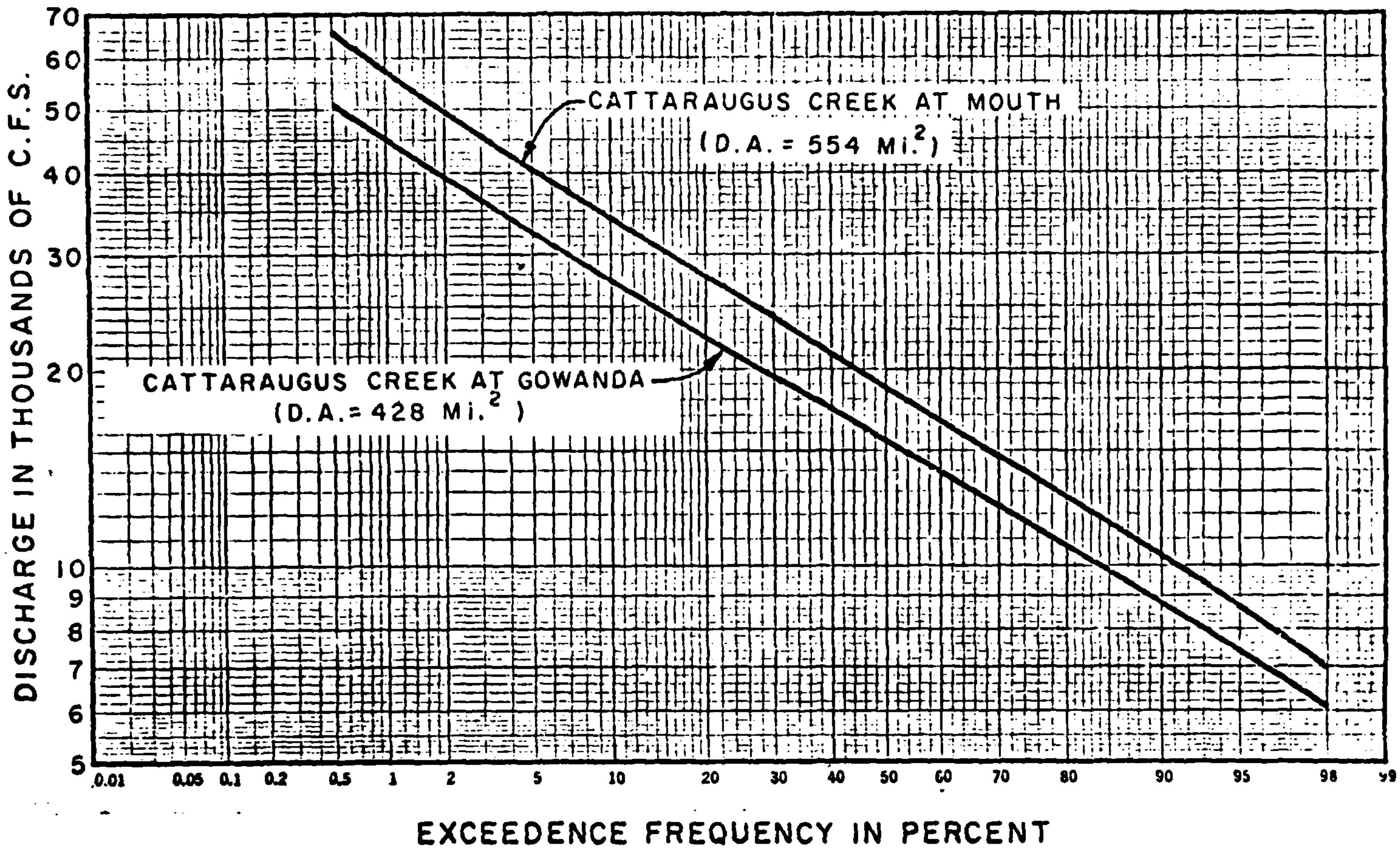


FIGURE B1

DISCHARGE-FREQUENCY CURVES

or during the early stages of a major flood. The more shear-resistant underlying gravel bed scours primarily during higher discharges. The creek stations upstream of the New York State Thruway have been demonstrated in Appendix F, Sediment Transport in Cattaraugus Creek, to meander. Meandering is an indicator of sediment transport. Gravel operations in the reaches 2 miles upstream from the mouth remove an estimated 25,000 to 50,000 yards of gravel annually. These operations tend to reduce the bedload delivered to the downstream reaches by, in effect, creating a sediment trap.

SEDIMENT LOAD ESTIMATES

B3. The channel meanders, review of channel bottom composition, gravel operations, and beach composition indicate a sand-and-gravel bedload is being transported through the lower reaches of the creek and is being deposited in the lake littoral zone. The bedload quantity has been estimated by several methods described in Appendix F. The results of the studies are summarized in Table B1 and described below.

B4. Method A was an estimate of sediment transport based on the volume of material removed from the erosion of a bank and deposition on a point bar located immediately downstream of the bank. This method yields a bedload of 12,000 tons per year, or approximately 10,000 cubic yards per year, of sand and gravel in the reaches upstream of the New York State Thruway. This is a minimum figure, since some material would be expected to move in the bed without being deposited on the immediate downstream point bar. Gravel is being removed from the point bars at a rate two to five times greater than the 10,000 cubic yards estimated from the meanders. This suggests a considerably greater annual bedload transport than calculated.

B5. Method B was an estimate of bedload based on the work of Archer and La Sala.[1] The suspended load was calculated from a sediment-rating curve for Cattaraugus Creek determined by field measurements. An annual hydrograph was used with the sediment-rating curve to estimate the

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[1] Archer, R. J., and A. M. La Sala, "A Reconnaissance of Stream Sediment in the Erie-Niagara Basin, N. Y.," NYS Water Resources Commission, Basin Planning Report, ENB-S, 1968.

TABLE B1

ESTIMATES OF ANNUAL SEDIMENT TRANSPORT

AT THE MOUTH OF CATTARAUGUS CREEK

Method	Description	Total Load tons/year	Bedload tons/year
A	Meander migration rates (upstream of river mile 2)...............	--	12,000
B	Suspended sediment concentration		
	Archer & La Sala, 1968.........	1,570,000	140,000
	Fahnestock, Nummedal, Apmann & Brownlie, 1972 water year....	780,000	71,000
C	Sediment yield of drainage basin		
	U.S.D.A., Soil Conservation Service, 1974..................	520,000	47,000[1]
D	Bedload transport equation, 25 yr. average		
	Einstein.............lower reach		12,000
	.............upper reach		36,000
	Meyer-Peter & Müller.lower reach		10,000
	.upper reach		28,000
	Kalinske............lower reach		30,000
	.............upper reach		53,000
E	Computer simulation.............		35,000

[1]Assume bedload equal 10 percent of suspended load and total load equal suspended plus bedload.

suspended load. The bedload was estimated to be 10 percent of the suspended load. This percentage was derived for the Genesee and Potomac Rivers and employed on Cattaraugus Creek. Archer and La Sala estimated the Cattaraugus bedload to be 71,000 tons per year, using long-term stream flow records. Fahnestock, Nummedal, Apmann and Brownlie applied a sediment-rating curve modified from Archer and La Sala to the 1972 water year, and estimated a bedload of 140,000 tons per year. The 1972 year had a 2-year recurrence flood which accounted for approximately 45 percent of the annual bedload in one year. This bedload doubled the long-term mean rate estimated by Archer and La Sala. 140,000 tons may be representative of the 1972 water year, but is high for an average year. Consequently, 71,000 tons per year may be more representative of a mean annual bedload, whereas 140,000 tons indicates the order-of-magnitude increase in bedload due to a single large event. Substantially greater bedloads would occur during a longer-period recurrence flood.

B6. Method C was a bedload calculation performed by the Soil Conservation Service.[2] The total sediment load supplied by the drainage basin was estimated by considering the erodability of the soils, the land use, and precipitation rate. An annual sediment load of 520,000 tons was estimated. Assuming the bedload is 10 percent of the suspended load, the bedload is 47,000 tons per year.

B7. Method D comprises theoretical calculations of bedload based on the methods of Einstein, Meyer-Peter and Muller, and Kalinske. Table B2 summarizes the bedloads computed for flows greater than 1,000 cfs over a 25-year period. Bedloads were computed for a station in the lower 3/4-mile of creek and for a station located 2 miles upstream from the mouth. The bedload computations presented in Appendix F did not include values for flows of 5,000 cfs and less for the upstream reaches. This report has included these calculations. The bedloads computed by each of the methods varies by an order of magnitude from the downstream to upstream reach. The annual bedloads for the upstream reach are relatively comparable for each method at approximately 90,000 tons per year. The downstream reach has 10,000 to 30,000 tons per year,

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[2] U. S. Dept. of Agriculture, Soil Conservation Service, "Erosion and Sedimentation Theory, Cattaraugus Creek, N. Y.," 1974.

TABLE B2

COMPUTED ANNUAL AVERAGE SEDIMENT TRANSPORT IN CATTARAUGUS CREEK BASED ON 25 YEARS OF WATER RECORDS (FLOW DATA FROM: CORPS OF ENGINEERS, 1968)[3]

Discharge (cfs)	Number of Daily Occurrences	Sediment Load, Tons: Einstein 0-0.75 mi	Einstein 2.0-2.2 mi	Meyer-Peter & Müller 0-0.75 mi	Meyer-Peter & Müller 2.0-2.2 mi	Kalinske 0-0.75 mi	Kalinske 2.0-2.2 mi
35,000	2	54,000	57,000	47,000	50,000	45,000	45,000
30,000	1	21,500	25,000	18,000	21,500	19,000	20,000
25,000	3	44,400	63,000	39,000	55,500	48,000	51,000
20,000	8	73,600	140,000	64,000	112,000	100,000	112,000
15,000	13	57,200	169,000	44,200	136,500	110,500	143,000
10,000	25	23,750	225,000	19,000	167,500	130,000	192,500
5,000	300	21,000	(1,320,000)*	15,900	(900,000)*	540,000	(1,050,000)*
1,000	1,500	1,500	(750,000)*	1,500	(450,000)*	15,000	(600,000)*
25 yr. total load, tons		295,450	(2,749,000)*	247,100	(2,045,000)*	992,500	(2,213,000)*
Annual load, tons		11,818	(109,960)*	9,884	(81,800)*	29,700	(88,520)*

*Not included in Reference 1.

[3] "Flood Plain Information, Cattaraugus Creek and Thatcher Brook - Irving, Sunset Bay and Gowanda, N.Y.," U. S. Army Corps of Engineers, Buffalo, New York, 1968.

depending on the method. Several factors can contribute toward the difference of 60,000 to 80,000 tons per year estimated for the upstream and downstream reaches. Gravel operations have taken as much as 50,000 tons per year out between the points of analysis. The creek could have responded to the decrease in load entering the downstream reaches by increasing the depth establishing a new equilibrium between hydraulic discharge, sediment transport potential, and material supply. Other factors, such as the influence of lake level and over-bank flooding, and deposition during major events, may account for a significant portion of the discrepancy. The detailed analysis of these factors is beyond the scope of the appendices of this study.

B8. Method E was a calculation of bedload using the Einstein equation. The transport was calculated for water years 1971 and 1972. An average value of 35,000 tons per year was postulated as being representative of a typical year.

B9. The five methods of computing bedload yield a wide range of bedload transport rates in the downstream reach, ranging from 10,000 tons per year to 140,000 tons per year. A bedload of 20,000 to 50,000 tons per year is an order-of-magnitude estimate of the annual bedload. The annual bedload cannot be estimated accurately due to the dependency of factors such as the lake level variations, sequence of flows, and upstream gravel operations. These factors complicate the system. The estimate of 35,000 tons per year is assumed to be a representative figure for application to design and maintenance.

EFFECT OF LAKE LEVEL ON CHANNEL DEPTH

B10. The sediment transport rate in the lower reaches of the creek is, in part, dependent upon the lake stage. During a seasonally high lake stage, the creek has a greater depth of water than during seasonally low stages. The scour potential is less for seasonally high lake stages than for seasonally low lake stages for a given reach and discharge. When the lake stage goes down, the flow area decreases and velocities increase, enhancing potential sediment transport. The lake levels are generally high during the spring and low in the fall and winter, as indicated in Figure B2. The sediment transport rate is also a function of the creek discharge. The mean monthly discharges for the 20 years from October, 1953, to September, 1973, are listed in Table B3 and plotted in Figure B3.

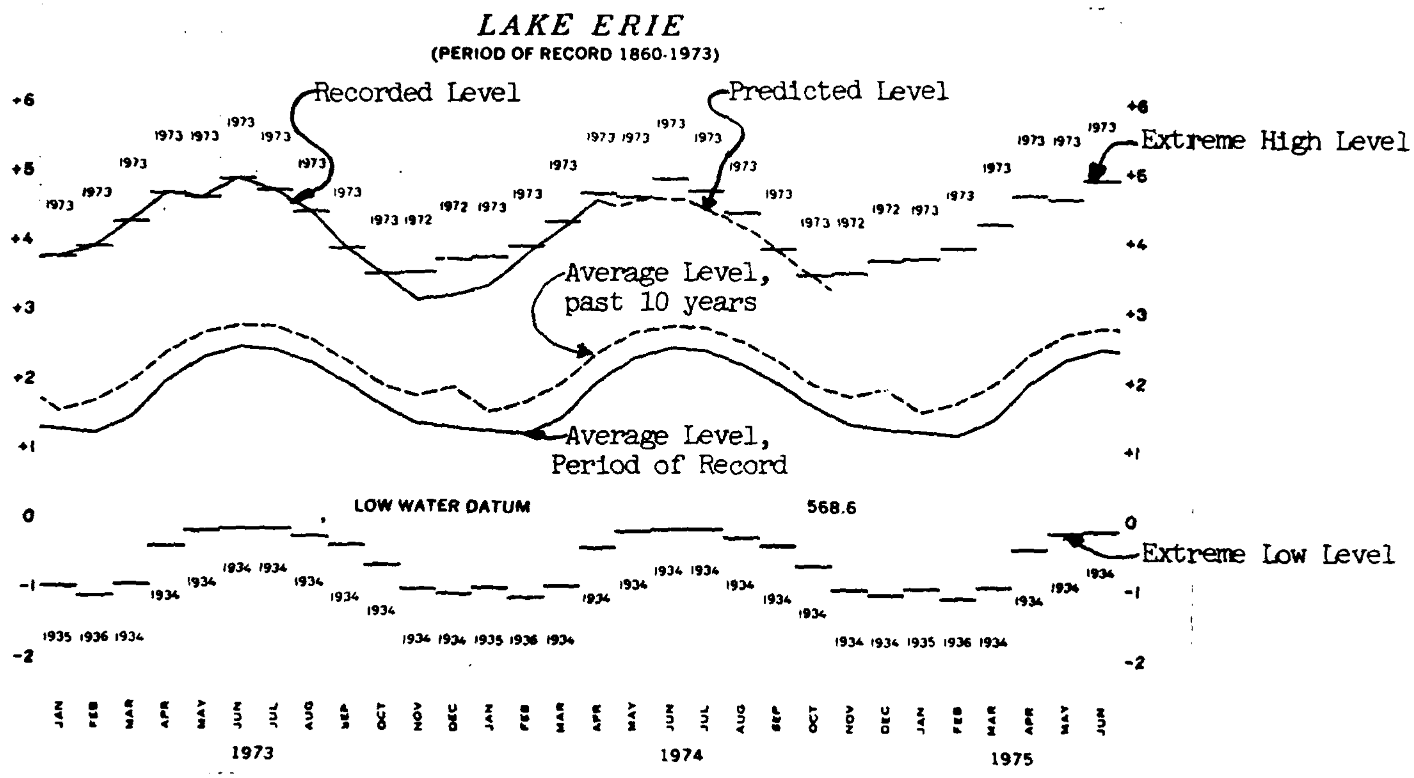


FIGURE B2

AVERAGE MONTHLY LAKE LEVEL FLUCTUATIONS

TABLE B3

MEAN MONTHLY DISCHARGES IN CATTARAUGUS CREEK

OCTOBER, 1953, TO SEPTEMBER, 1973

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Gowanda	312	627	952	786	857	1583	1505	666	443	265	202	265
Project Site	402	809	1228	1014	1106	2042	1941	859	571	330	261	342

The discharges were taken from the records of the U. S. Geologic Survey gage at Gowanda and multiplied by a 1.29 factor to account for the increased watershed contributing discharge to the project site. The high discharges occur during February through April. The mean monthly discharges decrease rapidly for the summer and fall months. The high discharges occur generally during periods of seasonally high lake levels. The spring floods have the greatest potential to scour and shape the channel. The lake levels drop and the discharges decrease during the summer. Under these conditions, deposition of finer-sized sediment is most likely to occur in the lower reaches. The depth of water in the channel, therefore, decreases due to both sediment deposition and decreasing lake levels. The decrease due to deposition is minor compared to that due to the decrease in lake level.

B11. The elevation of the creek bottom is a function of both long-term and short-term lake levels. Creek soundings were taken in November, 1935, May, 1940, and June, 1975. Comparative sections at a station opposite Newton's fish-house at Station 23+00 and at the downstream end of the island at about Station 30+00 are shown in Figure B4. The lake levels during each sounding are indicated on Figure B4. The 1935 soundings were taken in November following a period of low seasonal creek discharge and low long- and short-term lake levels. This set of soundings indicates the greatest depths below LWD. The lake levels were on a long-term rise from 1935 to 1940. The 1940 soundings were taken during a seasonal high lake stage immediately following the spring flooding. The maximum depths below LWD were less than the 1935 soundings. The profile, however, indicates an erosion from 1935 in a large section of the

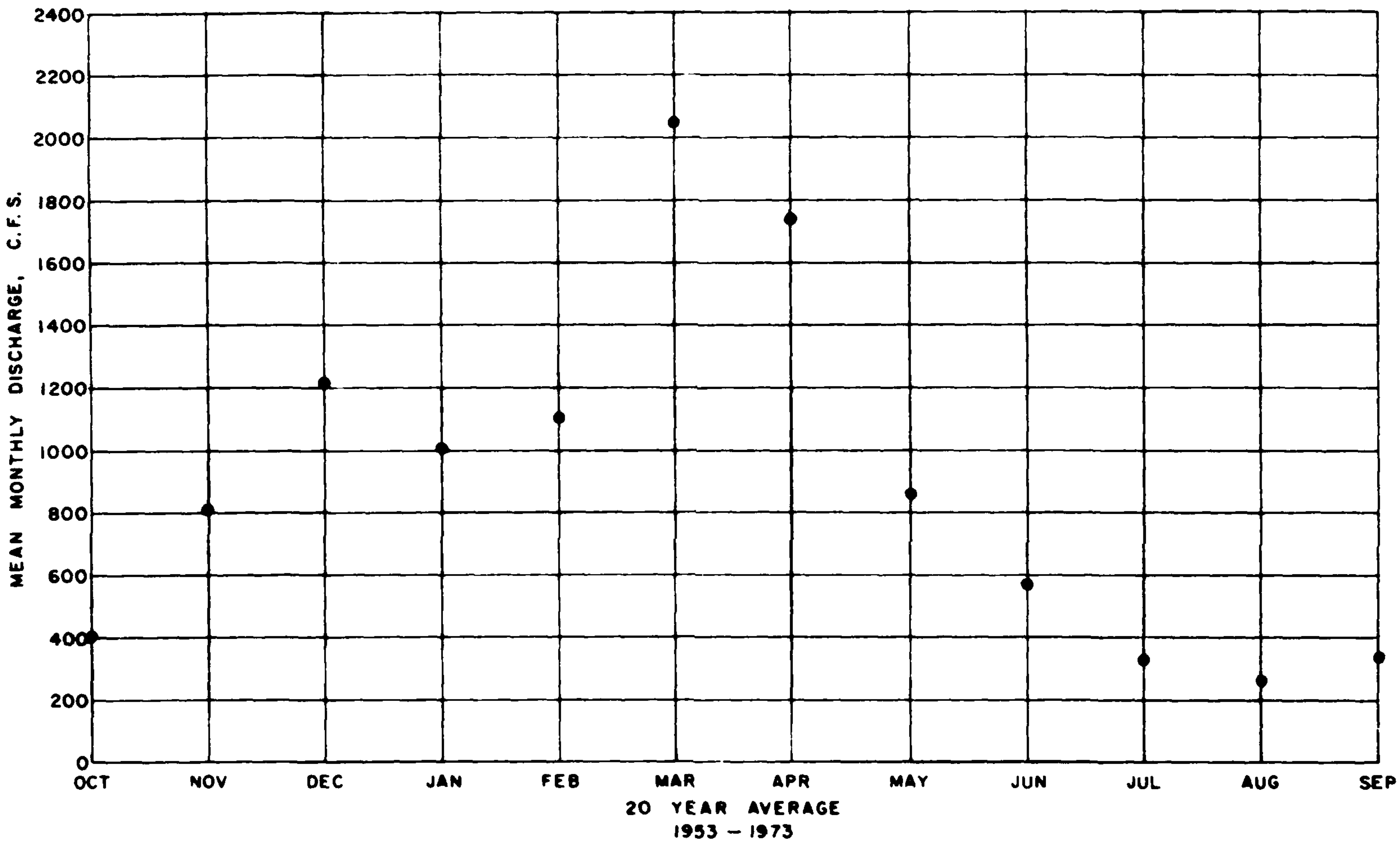
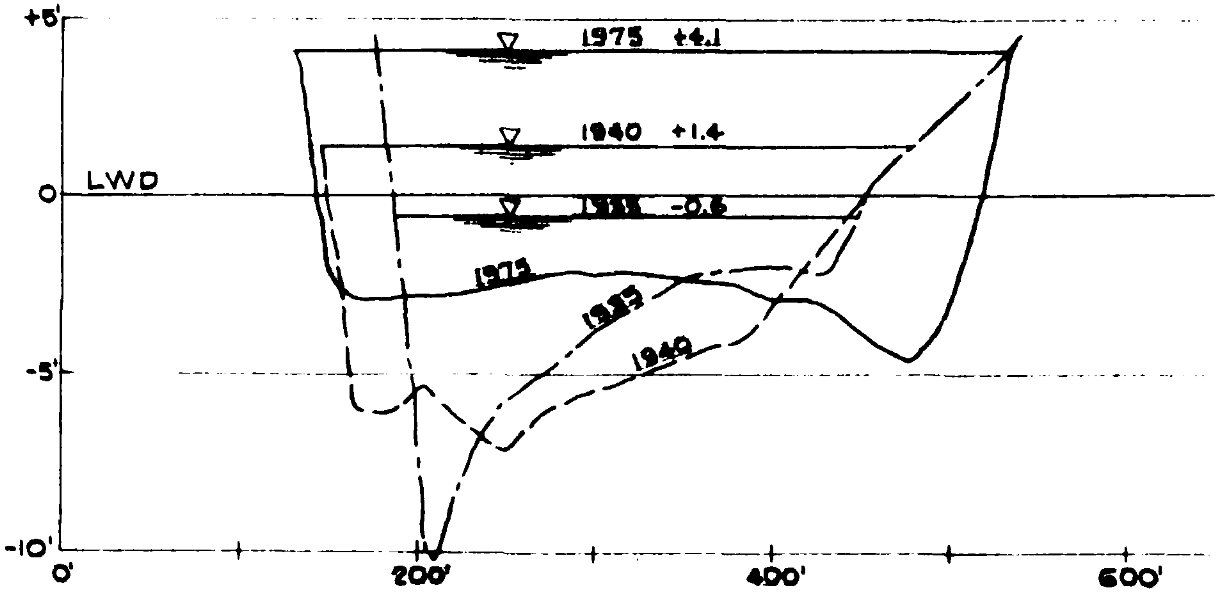


FIGURE B3

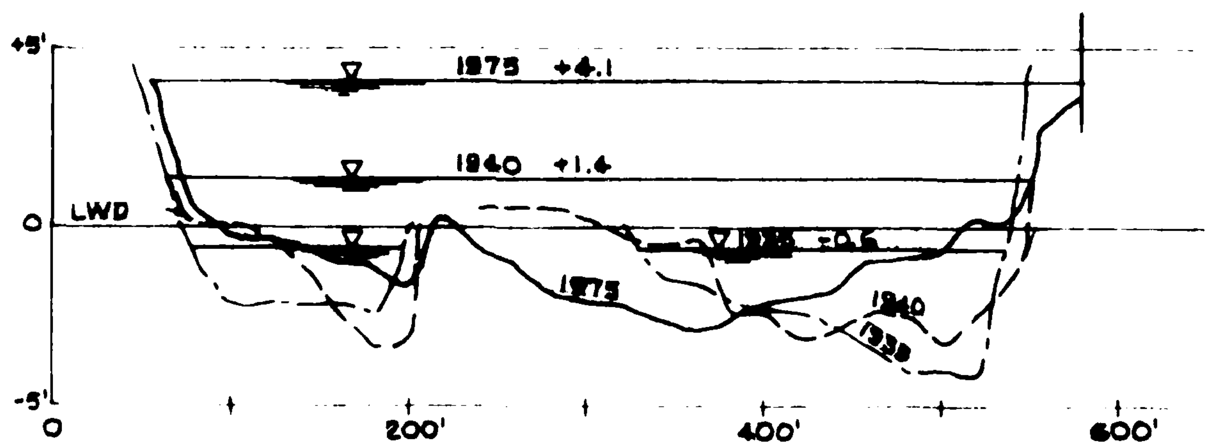
MEAN MONTHLY DISCHARGES

CATTARAUGUS CREEK



STATION 23+00±

NEWTON'S FISH HOUSE



STATION 30+00±

DOWNSTREAM END OF ISLAND

FIGURE B4

COMPARATIVE CREEK SOUNDINGS

channel at Station 23+00, increasing the flow area but not maximum depth. The decrease in maximum depth is attributed in part to the long-term rise in lake level. The decrease in depth along the centerline is attributed to the floods that had occurred during the preceding months. These floods scoured the channel depths during the high spring discharges. A meaningful comparison of 1935 and 1940 cross-sections is difficult due to the differences in lake level and seasons. The 1974 soundings were taken during a period of high, long-term and seasonal lake levels following the spring flooding. The cross-section at Station 23+00, near Newton's fish-house, indicates a large deposition from the 1935 and 1940 profiles to 1975 profiles and a change in location of maximum channel depths from the left bank to the right bank. This tends to support an hypothesis that the channel bottom follows the rise and fall of the long-term trends in lake level and seasonal variations in lake level, coupled with seasonal distribution of discharge. Due to the scarcity of data, the hypothesis cannot be proven or improved upon without a detailed sediment-transport study.

DESIGN CHANNEL DEPTH

B12. The preceding discussion has application to the design philosophy. An hypothesis has been postulated that the creek invert elevation is a function of long-term and short-term lake levels. Soundings made in 1975 during high lake levels have a shallow depth of channel relative to LWD. During the ensuing months into summer, the lake level is anticipated to decrease approximately 1.5 feet. Should a long-term decrease in lake levels occur, the creek should scour material and deposit it in the lake, primarily during high discharges in the spring. The water level within the channel during the survey was +4.1 feet LWD and the channel depth was approximately -2 feet LWD. This renders a water depth of approximately 6 feet which is sufficient for current navigation needs. The lake level decreases approximately 1.5 feet from the spring through the summer. Consequently, the depth of water during the navigation season would be 4.6 feet. One and one-half feet of material would have to be removed in order to maintain a 6-foot navigation depth. The quantity of material to be removed should, therefore, be a relatively constant amount and independent of the lake level. Should a -6-foot LWD channel be required, the quantity of material would vary considerably with long-term lake levels, assuming that the creek bottom tends to follow the lake level over a long term. During high lake levels, a greater deposition would be expected in this type of channel. During low lake levels, the channel would be closer to equilibrium and there would be less maintenance dredging. Based on the above discussion, a navigation depth of 6 feet relative to the summer water level is recommended for design. This recommendation to be effectively implemented must be combined with an annual maintenance monitoring program. The lack of mid-summer dredging during some years might curtail effective boat manuevering at random locations within the project limits.

CHANNEL IMPROVEMENTS

B13. The channel improvements proposed in the Phase I General Design Memorandum comprised dredging the lower 3/4-mile of channel to a navigation depth of -6 feet LWD. A computer simulation of the 1972 water year was conducted in Appendix F in an attempt to determine the deposition rates of material in the channel for the -6-foot LWD dredging plan. The simulation studied the trap efficiencies of the existing conditions and for low, average, and high lake levels under improved conditions. The results indicated that the channel was in equilibrium under existing conditions. The annual bedload was 35,000 tons. Trap efficiencies in the improved channel were .06, .14, and .18 for low, average and high lake levels, respectively. Assuming a trap efficiency of .14 as typical of the lower 3/4-mile of the improved creek channel, the average annual deposition is 3,920 cubic yards of material. Assuming this material deposits evenly over a channel width of 200 feet and length of 3,500 feet, a .15-foot annual deposition would occur.

B14. The bedload computation truncated the grain size at fine sand at .08 mm. Consequently, during low flows, finer grained material may comprise the bedload. This was observed in the sediment trap experiments described in Appendix F, where the traps filled with considerably finer grained material than was dredged to create the trap. Review of the distribution of the material that filled the traps in the lower reaches indicates that approximately 50 to 100 percent was assumed suspended load. The coarse material in the bed moves primarily during high discharges. The bedload calculations may indicate the rate of sand and gravel deposition; however, the silts and clays may contribute significantly higher sedimentation rates. The calculated deposition represents a minimum shoaling. A greater allowance should be made for maintenance dredging than indicated by the trap efficiencies calculated in Appendix F.

OUTER BASIN CHANNEL

B15. The outer channel between the breakwaters will be dredged to a depth of -5.5 feet LWD. This channel may locally have a greater tendency to shoal than the creek channel due to the greater depth and wider cross-section at the existing creek mouth. The entrance should, however, maintain a relatively greater depth than the station at the river mouth due to the confined flow area between the breakwaters and local scour which occurs on the outer bend of the channel.

EFFECT OF IMPROVEMENTS ON LITTORAL DRIFT SOURCE

B16. The channel dredging will disrupt a quasi-equilibrium bottom configuration which should result in a tendency for the channel to act as a sediment trap. This should reduce the quantity of bedload delivered to the lake. The coarser fraction of the bedload should first be deposited on the upstream end of the channel. The calculated trap efficiency of .14, coupled with the estimated annual bedload of 35,000 tons, results in approximately 5,000 tons being deposited in the channel and 30,000 tons being transported into the lake. Consequently, the rate of material transported to the creek mouth and the grain size will be reduced. Maintenance dredging will be required to maintain the navigation depth. This dredging should be performed after the spring floods prior to deposition of fines during lower summer flows. The coarse dredged material should be placed on the downdrift beach to maintain the alignment and prevent a long-term erosion.

B17. Construction of the breakwaters will extend the effective mouth of the creek 800 feet lakeward of its present location. Presently, material is deposited upon entry into the lake. The coarser fraction is deposited near shore. Waves distribute this material, forming bars which eventually migrate onto the beach. The finer portion of the sediment load may be carried lakeward out of the region where the waves can cause shoreward transport of the material. The structures will introduce all sediment fractions into the lake at a greater depth of water, approximately -8 feet LWD. The breakwater alignment was designed and tested in a hydraulic model study[4] to distribute sediment discharge onto the shore by wave and current action. Since the material is to be introduced into the lake at a greater depth, a larger fraction of fine material may be lost offshore than under present conditions. The coarser material will be deposited in deeper water and will not be as likely to be transported to the beach. A shoal could form off the mouth of the entrance. This shoal may have to be periodically removed for navigation purposes and to nourish the downdrift beach.

MAINTENANCE DREDGING

B18. Deposition of sediment load in the navigation channel is estimated to be approximately 5,000 tons per year. The initial channel dredging is approximately 35,000 cubic yards. Periodic dredging will be required in order to maintain the channel at a 6-foot navigation depth. Since the bedload did not include material finer than fine sand, the estimated quantity is most likely low. An allowance should be made for approximately 10,000 cubic yards per year for maintenance dredging. This should be adequate for removal of material from the channel and the shoal which may form off the mouth of the creek and provide littoral drift nourishment for the downdrift beach. The material may be used for beach nourishment, provided a study proves that the material is not contaminated with unsafe levels of radioactivity. The maintenance dredging will vary considerably from year to year due to occurrence of extreme-event floods and, over the long-term, due to changes in lake level.

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[4] Bottin, R.R., and C.E. Chatham, "Design for Wave Protection, Flood, Control, and Prevention of Shoaling, Cattaraugus Creek Harbor, New York, WES Report. Appendix A.

LITTORAL PROCESSES

GENERAL

B19. The purposes of this section are to define the littoral processes at Cattaraugus Creek along the shoreline of Lake Erie and to predict possible effects of the proposed flood control and harbor improvements on the littoral processes. The analysis is required to estimate the effect of the breakwater construction on the shoreline and to determine the annual maintenance required to stabilize the downdrift beach to the north. A detailed study of the littoral processes along the southeastern coast of Lake Erie and at the project site has been described by Appendix E.[5] This section summarizes portions of Appendix E and contains some analysis of the rates of littoral transport for engineering design and cost analysis purposes. The study is limited to a review of comparative aerial photographs and calculations of littoral drift transport based on the incident wave climate. Comparative profiles taken at long time intervals were not available to aid in calculation of beach profile changes. No existing structures were available to aid in quantifying the rates of littoral drift by means of estimating transport rates from accretion or erosion volumes. Minor dredging in the creek mouth was not recorded nor did it provide adequate data to estimate rates of filling.

CATTARAUGUS EMBAYMENT

B20. Cattaraugus Creek enters Lake Erie in a gentle arcuate embayment. The embayment extends 1.5 miles to the southwest to Hanford Bay and 1.5 miles to the northeast to Lotus Bay. The configuration of the Cattaraugus embayment is shown in Figure B5. The perimeter of the embayment is a beach comprising sand and some gravel-sized material. Walnut and Silver Creeks debouch into the lake two miles to the southwest of the project site. High shale bluffs form the shoreline to the southwest. The shoreline configuration along the embayment has more of a north-south

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[5] Nummendal, D., D. Shearer, R. Clemens, M. Hayes, L. Holmes, R. Fahnestock, D. Messinger, and J. Walton, "Littoral Processes and Sedimentation in the Cattaraugus Embayment, N.Y.," Report for U. S. Army Engineering District, Buffalo, New York, February, 1975. Appendix E.

trend than does the general shoreline of the lake in this area. The southern end of the embayment is partially sheltered from southwesterly wave attack by the land prominence and offshore shoals in the Walnut-Silver Creek area.

B21. The bathymetry of the project site shown in Figure B5 has a submerged delta derived from the river sediment discharge. The bottom contours are relatively regular to the north. A large, submerged ridge extends into the lake approximately 1000 feet south of the project site. This feature has not altered the local shore configuration as its refraction effects on the wave regimen would lead one to expect. This anomaly may be partially explained by the relative sharpness of the ridge which concentrates wave energy in a highly localized area. Minor changes in wave direction would shift the location of this focal point back and forth and tend to average out the net influence of the ridge in controlling the beach alignment. The ridge may act as a submerged groin, trapping some fine material that would otherwise be transported northward, as discussed in Appendix E.

SHORELINE CONFIGURATION

B22. Changes in configuration of the shoreline over a period of time were analyzed to determine possible patterns of erosion or accretion and historic aerial photographs were compared to determine the order of magnitude of shoreline changes. No large structures have been built within the embayment that would affect shore configuration or rates of littoral transport. On the other hand, no periodic profiles have been taken with which to analyze shore-area changes. During the recent stand of high lake levels, some structures on the south beach which were formerly fronted by a wide beach berm were destroyed by waves.

B23. Successive locations of the water line taken from five sets of aerial photographs during the period 1957 to 1975 are shown in Figure B6, and the average monthly water level reported for the month in which each set was taken is shown in Table B4. Figure B6 clearly reveals two important facts. One is that in each set of photos the shoreline to the south of Cattaraugus Creek if farther

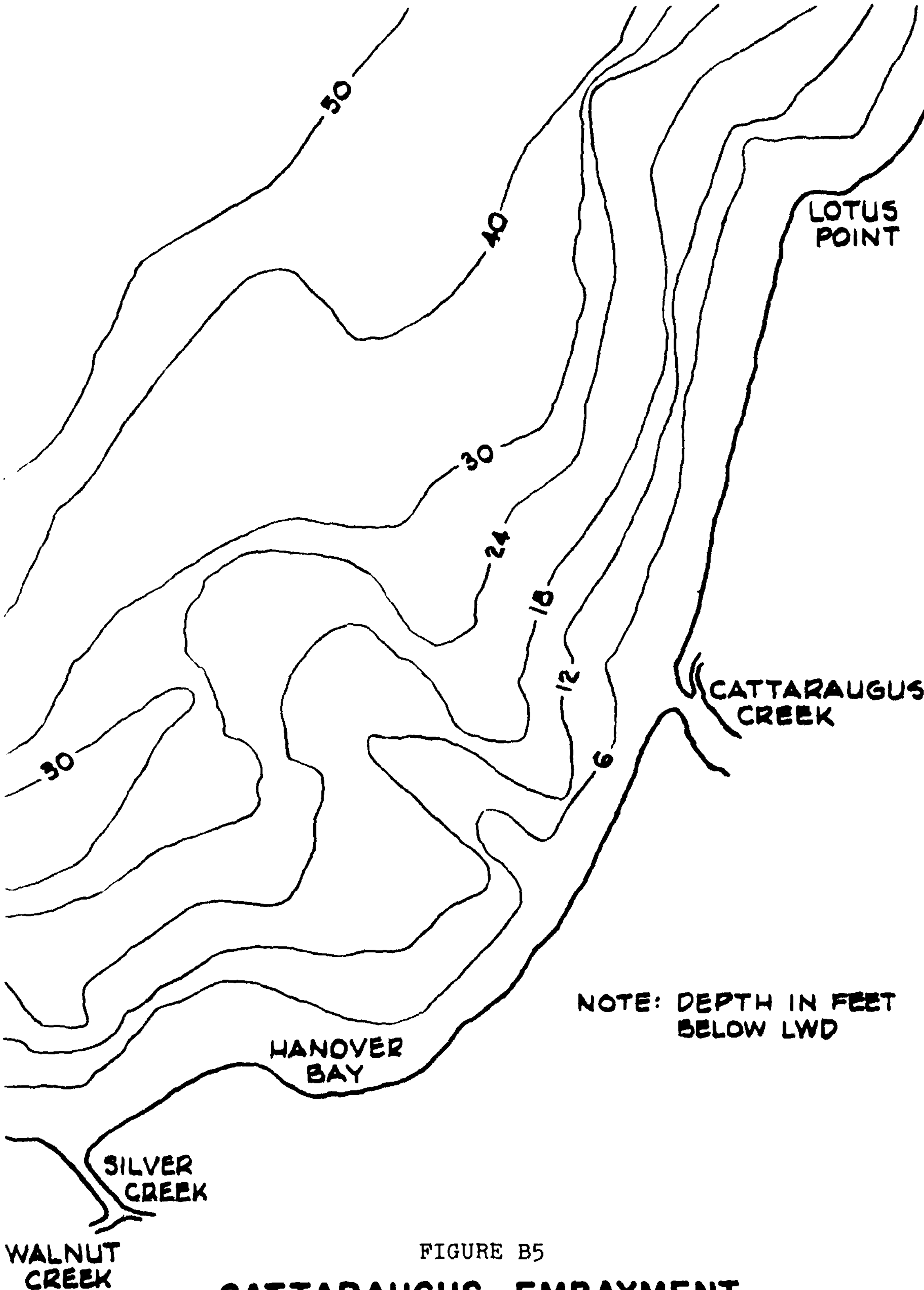


FIGURE B5

CATTARAUGUS EMBAYMENT

SCALE: 1:26,667

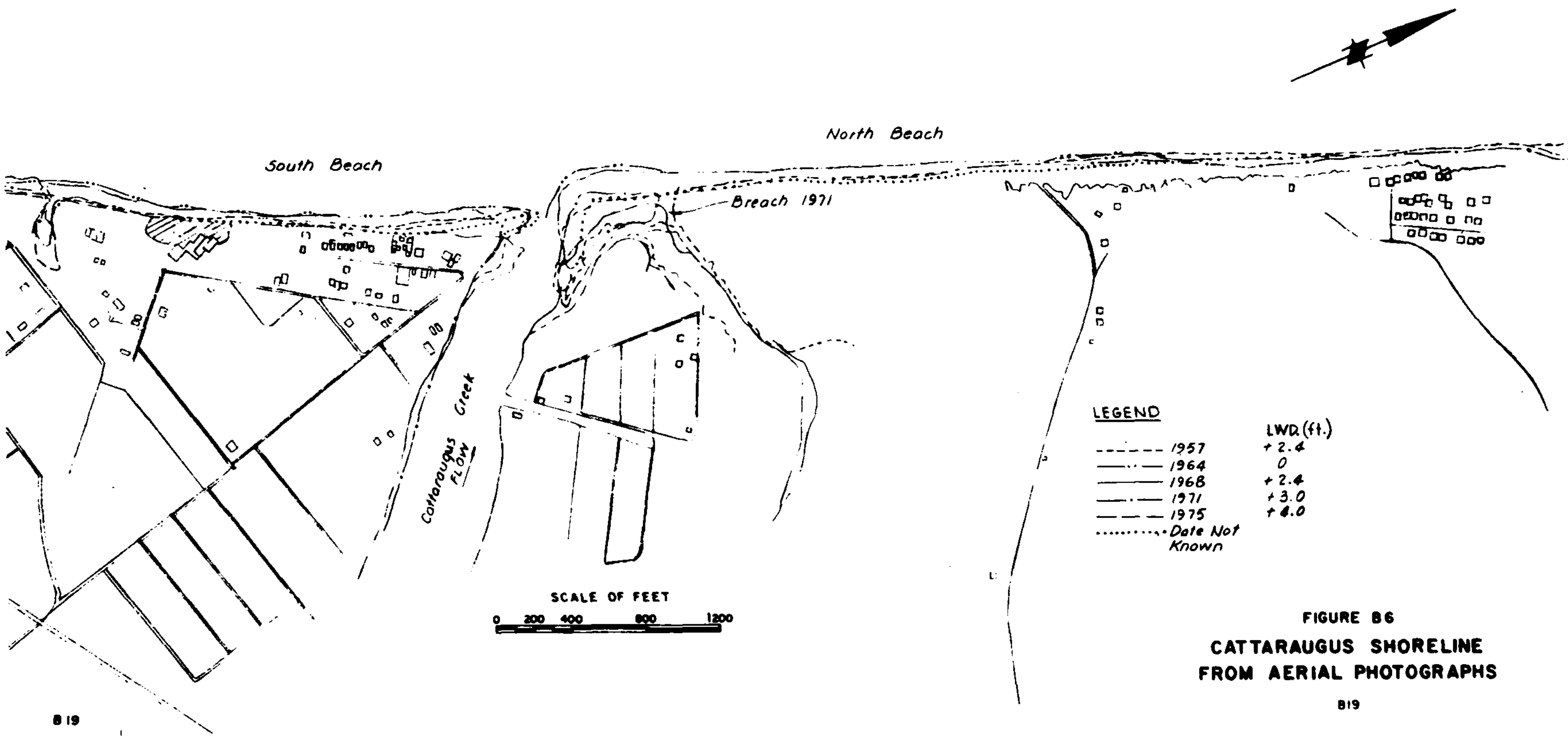


FIGURE B6
CATTARAUGUS SHORELINE
FROM AERIAL PHOTOGRAPHS

landward than that to the north. This, in part, attests to the role of Cattaraugus Creek as a source of littoral drift. The other fact is the relatively rapid change of the creek mouth configuration as compared to changes along the adjacent beaches. This attests to the sensitivity of the project-area shoreline to changes in incident waves, creek discharges, and lake levels, a factor which must be taken into account in the project design. Because of the frequent shifting of the creek mouth, design depths must be adequate to relate to any possible change of the shoreline from that of the project-document survey. The landward end of the north breakwater terminates in a particularly changeable shore segment, and quantity estimates may vary greatly with the timing of construction.

TABLE B4. SHORELINE ADJUSTMENT FOR AERIAL PHOTOGRAPHS

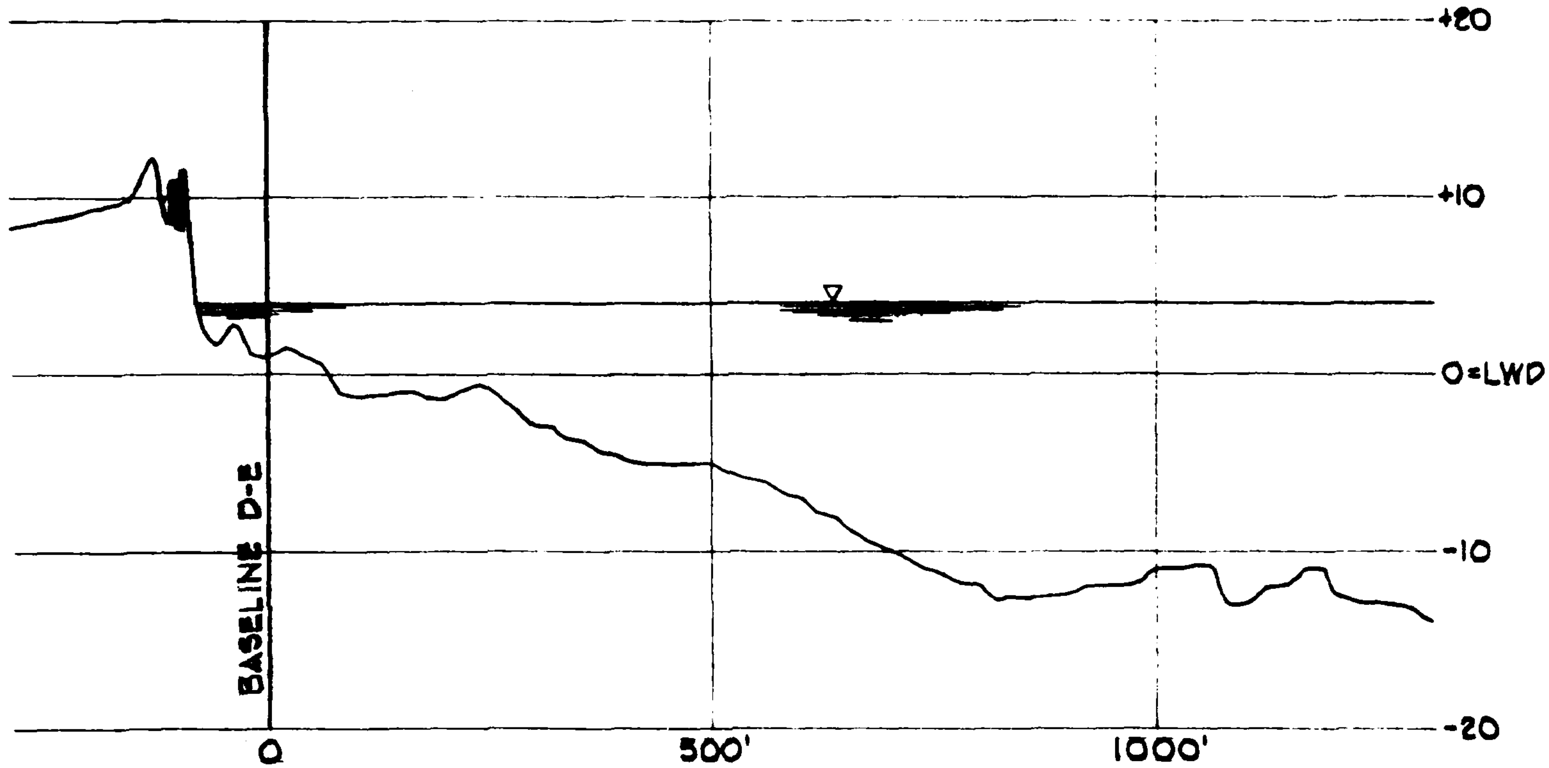
Year	Month	Lake Level IGLD (ft)	Lake Level LWD (ft)	Image vs. LWD Shore Position (Shoreline Retreat) with Beach Slope Assumed at 1:10 (ft)	Image vs. LWD Shore Position (Shoreline Retreat) with Beach Slope Assumed at 1:30 (ft)
1957	(Not given)	571±	+2.4	-24	-72
1964	October	568.6	0	0	0
1968	April	571.0	+2.4	-24	-72
1971	May	571.6	+3.0	-30	-90
1975	May	572.6	+4.0	-40	-120

B24. The photographic coverage spans a period of decreasing, low, rising, and high lake levels. The 1964 photographs show the shoreline in its farthest lakeward position. During this period, the lake level was low and close to LWD. The shoreline rapidly retreated during the next 8 to 10 years as the lake level rose to +4 feet LWD in 1975. Most of the retreat occurred during the rise which occurred prior to 1971. The 1957 and 1971 shorelines are in close general agreement. This tends to suggest that the beach is relatively stable.

B25. The shoreline retreat shown in Figure B6 may be attributed to erosion, changes in lake level, inaccuracy in drawing the shoreline due to distortion in the photographs, and lack of adequate controls in some areas. The latter effect is assumed minor. The retreat of the shoreline accounted for by changes in lake levels is difficult to determine accurately. Typical profiles of the adjacent beaches are shown in Figures B7 through B10. The profiles indicate a relatively mild offshore slope of 1:50 to 1:100. A sand bar, or in some cases a series of sand bars, is evident. The lake level intersects the beach on a relatively steep 1:10 slope. The water level is drawn at +4 feet LWD, which occurred during the 1975 survey. The retreat of shoreline from the 1964 shoreline is summarized in Table B4 for each photographic series and attendant lake level for a beach with a 1:10 slope. The present level of +4 feet LWD accounts for 40 feet of shoreline retreat on a 1:10 slope. The general maximum shoreline retreat on the beaches 1000 feet to the south and 1000 feet to the north is on this order of magnitude. Due to the complex nature of the slope, a 4-foot drop in water level to 1964 would expose a greater beach width in some areas than the 1:10 slope indicates. This is supported by the profiles on the southern beach. The beach would take on some intermediate slope during the lower lake level. Table B4 summarizes the shoreline retreat for a 1:30 slope. A 120-foot wider beach at low lake level results from this assumption. The maximum shoreline fluctuation at some distance from the creek mouth is 100 feet. Lake-level variations easily account for the observed shoreline changes. Long-term erosion is not evident nor can it be predicted by this method. Recent high lake levels may have caused some local erosion of dune and berm sand and damage to property, as evidenced by the steep beach slope fronting the seawall in Figure B7 at 2600 feet south of the creek mouth.

PREVIOUS STUDY

B26. Field observations documented littoral processes in Appendix E for specific storms. These observations indicated higher waves and longshore currents existed on the northern beaches than on the southern beaches for waves approaching from the west. The shoals located to the west sheltered the southwest embayment beaches. Littoral currents increased in strength from the southern beaches toward the northern beaches. A reversal in littoral currents was found during a northeast storm. The order-of-magnitude of sediment transport rates was not estimated; however, it was concluded from analysis of storms and studies of lithological sediment distributions that the net littoral drift transport is from southwest to northeast.



Buffalo District,
Corps of Engineers
Soundings - June 1975

FIGURE B7

BEACH PROFILE-STATION 26+00 SOUTH

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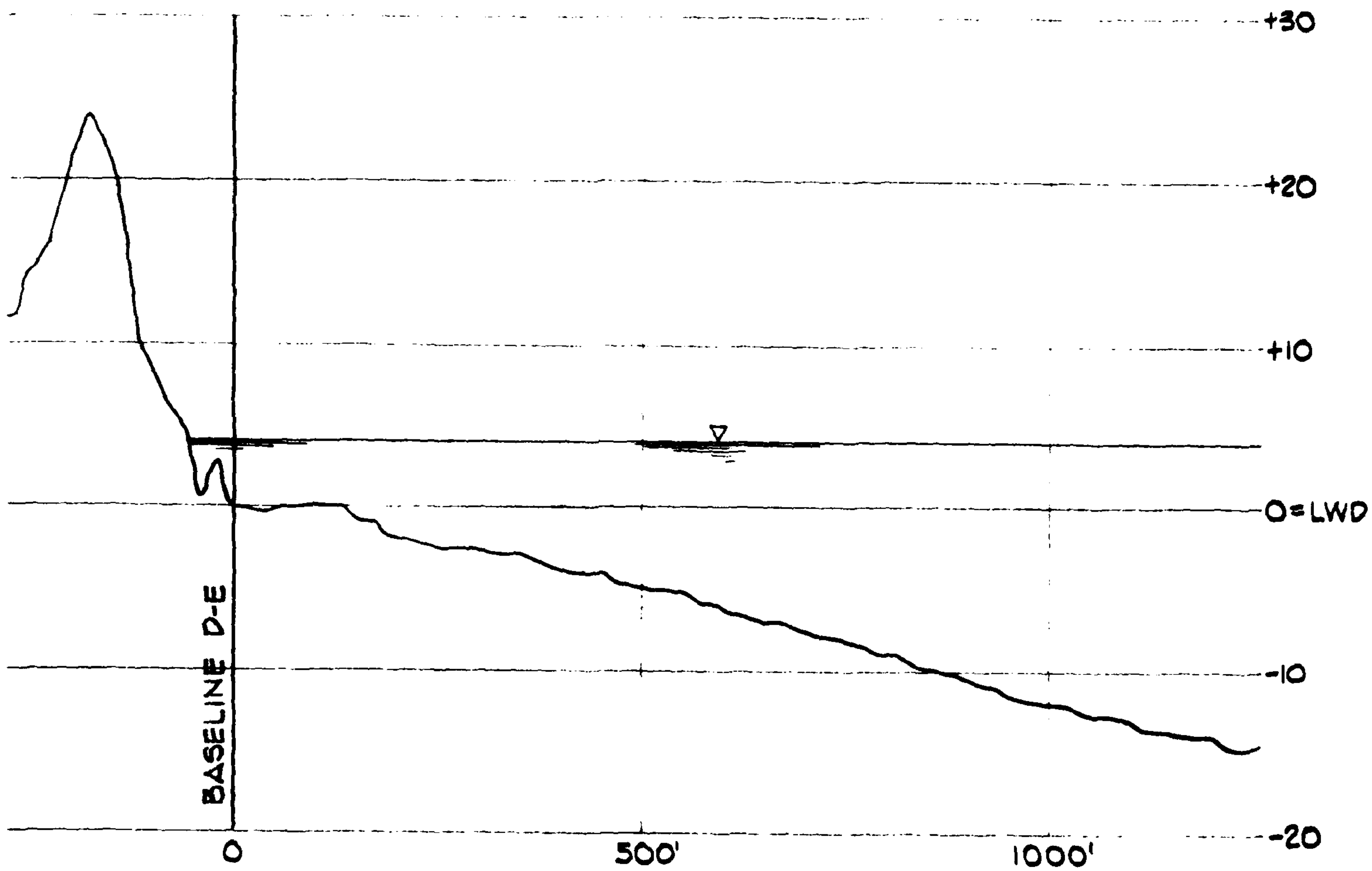
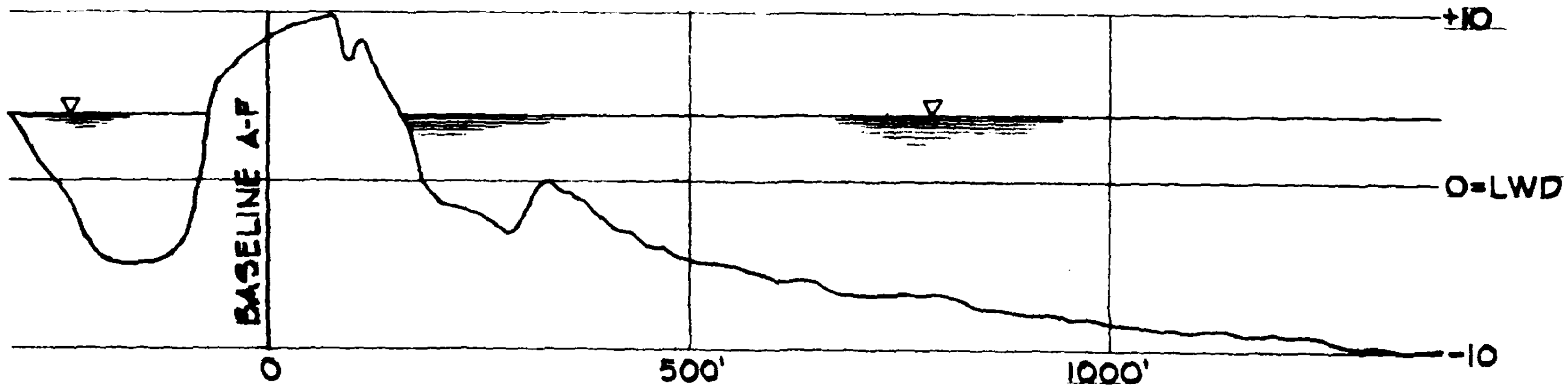


Buffalo District,
Corps of Engineers
Soundings - June 1975

FIGURE B8

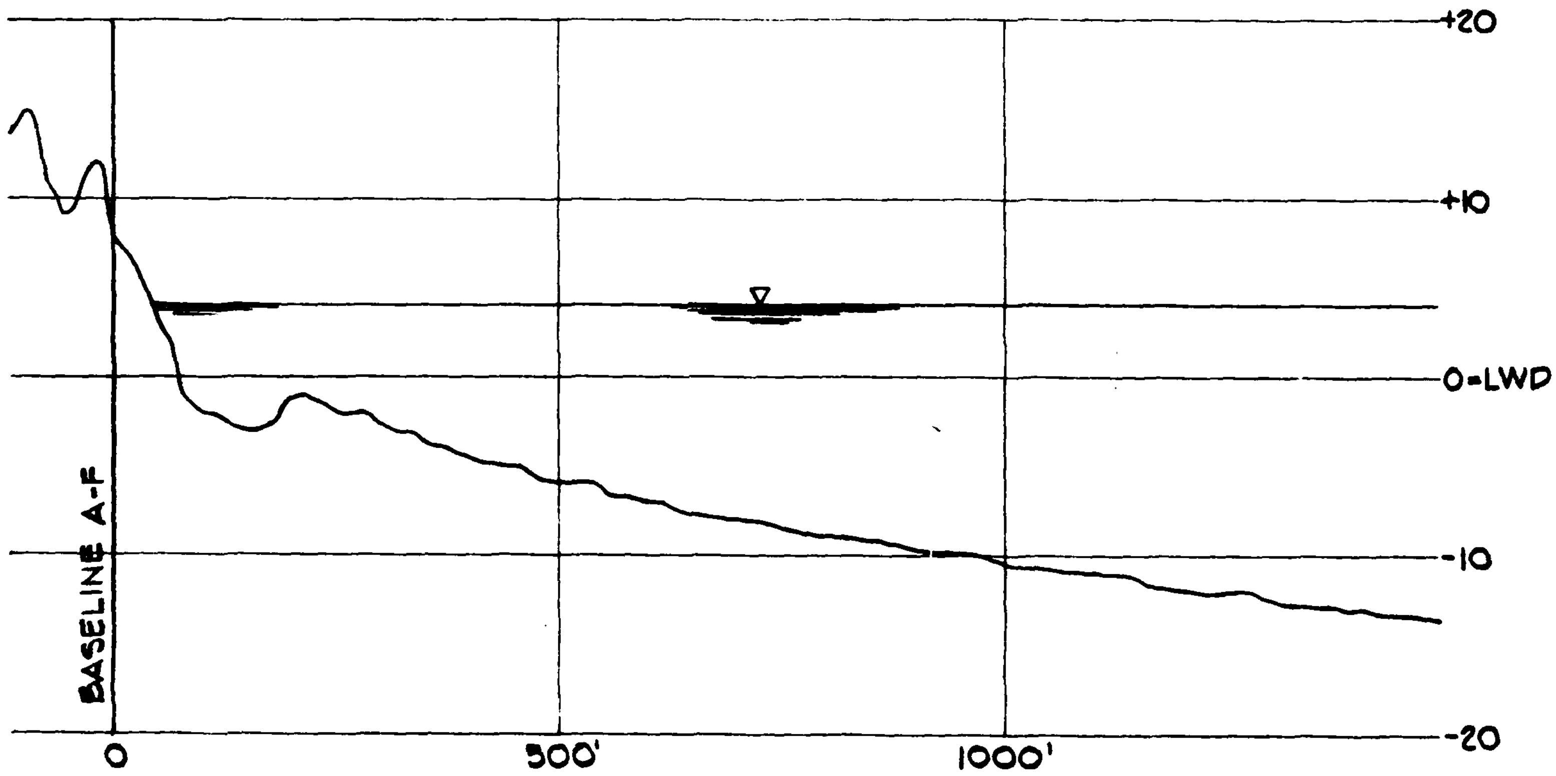
BEACH PROFILE-STATION 11+00 SOUTH



Buffalo District,
Corps of Engineers
Soundings - June 1975

FIGURE B9

BEACH PROFILE-STATION 12+00 NORTH



Buffalo District,
Corps of Engineers
Soundings - June 1975

FIGURE B10

BEACH PROFILE-STATION 24+00 NORTH

B27. Cattaruaugs Creek is a prime contributor of siltstone, sand stone, and crystalline rock fragments to the beaches in the embayment. Silver and Walnut Creeks have smaller watersheds and pass through more resistant shale than Cattaraugus. These creeks contribute dark Hanover shale, crystalline rock fragments, quartzite, and chert into the embayment; however, at a presumed lesser rate than does Cattaraugus Creek. The shale cliffs extending to the west of Silver Creek are believed to contribute an insignificant amount of littoral drift. Offshore sources are also believed to be insignificant. The beach material comprises sands with gravel. The mean diameter of the sandy material on the beach is approximately $\emptyset = 2$.

LITTORAL TRANSPORT RATE

B28. The rate of littoral drift transport was estimated from an energy-budget calculation based on incident wave characteristics taken from the work of Saville.[6] The rate of littoral drift is required to determine the probable effects of structures on the adjacent shorelines and to recommend remedial measures for adverse effects. The wave climate was an interpolation of wave climates at Buffalo and Erie. Both sites are removed from the project site, having different wind and fetch parameters. The theoretical calculations indicate the potential rates of transport for design purposes and to predict probable effects of the structure on the littoral environment. Consequently, the results of the analysis are approximate and are intended to be representative of the order-of-magnitude of drift rate. Table B5 summarizes the hours duration of wave episodes for each direction and period. Eleven sets of refraction diagrams were drawn at an average annual lake level representing these period and direction groupings. Refraction coefficients and azimuths representative of the reaches 1000 feet north and south of the project site are summarized in Tables B6 and B7, respectively.

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[6] Saville, T., "Wave and Lake Level Statistics for Lake Erie," TM No. 37, BEB, 1953.

TABLE B5

HOURS OF DURATION OF WAVES AT CATTARAUGUS
FOR 3-YEAR, ICE-FREE PERIOD FROM VARIOUS DIRECTIONS

Direction	Period (sec) 1-2	2-3	3-4	4-5	5-6	6-7
WSW	12	268	820	312	90	36
W	78	660	612	189	66	0
WNW	54	234	222	42	6	0
NW	72	438	426	42	0	0
NNW	60	522	252	0	0	0
N	66	378	54	0	0	0
NNE	78	540	246	6	0	0

TABLE B6. REFRACTION COEFFICIENTS

NORTH REACH

Direction	T = 1.5 K_r	T = 1.5 A_z	T = 2.5 K_r	T = 2.5 A_z	T = 3.5 K_r	T = 3.5 A_z	T = 4.5 K_r	T = 4.5 A_z	T = 5.5 K_r	T = 5.5 A_z	T = 6.5 K_r	T = 6.5 A_z
WSW	--	--	--	--	--	--	.52	-82.0	.52	-82.0	.52	-82.0
W	.98	-86.5	.98	-86.5	1.00	-85.0	1.00	-85.0	1.00	-85.0	--	--
WNW	1.00	-69.0	1.00	-69.0	.99	-68.0	.99	-68.0	.99	-68.0	--	--
NW	.94	-50.0	.94	-50.0	.93	-48.0	.93	-48.0	--	--	--	--
NNW	.88	-31.5	.88	-31.5	.88	-31.5	--	--	--	--	--	--
N	.57	-18.5	.57	-18.5	.57	-18.5	--	--	--	--	--	--
NNE	--	--	--	--	--	--	--	--	--	--	--	--

TABLE B7. REFRACTION COEFFICIENTS

SOUTH REACH

Direction	T = 1.5 K_r	T = 1.5 A_z	T = 2.5 K_r	T = 2.5 A_z	T = 3.5 K_r	T = 3.5 A_z	T = 4.5 K_r	T = 4.5 A_z	T = 5.5 K_r	T = 5.5 A_z	T = 6.5 K_r	T = 6.5 A_z
WSW	--	--	--	--	--	--	--	--	--	--	--	--
W	1.00	91.5	1.00	91.5	.90	89.0	.90	89.0	.90	89.0	--	--
WNW	1.00	65.0	1.00	65.0	1.08	74.0	1.08	74.0	1.08	74.0	--	--
NW	.93	43.0	.93	43.0	.86	48.5	.86	48.5	--	--	--	--
NNW	.87	34.0	.87	34.0	.87	34.0	--	--	--	--	--	--
N	.79	14.0	.79	14.0	.79	14.0	--	--	--	--	--	--
NNE	--	--	--	--	--	--	--	--	--	--	--	--

B29. The wave energy and direction of wave approach at breaking were calculated for the beaches north and south of the breakwater for each wave condition by methods summarized in the following discussion. Refraction parameters listed in Tables B6 and B7 were applied to the appropriate wave condition. This transformation yields the equivalent deep-water wave height. The equivalent deep-water wave direction was determined assuming straight and parallel contours lakeward. This step is required to transform the wave to a breaking wave condition over straight and parallel contours. The procedure takes into account the effects of the irregular bathymetry lakeward of the 10-foot contour, but not landward. Since the calculation is for a typical reach, no significant error is introduced into the results. The breaker height and direction of propagation were solved by simultaneous solution of five equations. The first equation is the refraction equation:

$$\frac{\sin \alpha_b}{\sin \alpha_o} = \frac{C_b}{C_o} = \tanh (kd) \qquad (1)$$

Where α_b equals the wave angle of approach at breaking; α_o is the hypothetical deep-water wave direction; C_b is the wave celerity at breaking; C_o is the deep-water wave celerity, and kd is equal to $2\pi d \div L$, where L is the wave length and d is the breaker depth.

The breaking wave height, H_b, related to the deep-water wave height, H_o, is given by:

$$\frac{H_b}{H_o} = .76 S^{1/7} (H_o/L_o)^{-1/4} \qquad (2)$$

Where S is the beach slope and L_o is the deep-water wave length.

The deep-water wave height in equation (2) is replaced by the equivalent deep-water wave height, H_o':

$$\frac{H_o'}{H_o} = \frac{\cos \alpha_o}{\cos \alpha_b} \qquad (3)$$

The breaking depth, d_b, is assumed proportional to the breaker height, H_b:

$$d_b/H_b = c \qquad (4)$$

For the purpose of this calculation, the constant, c, was chosen to be unity. The wave length at breaking is given by the dispersion relationship:

$$L_b = L_o \tanh(k_b d_b) \qquad (5)$$

The preceding five equations were solved simultaneously by computer. The input was the deep-water wave data, the refraction coefficients, and angle of approach at each station which were determined by the refraction analysis. An average beach slope, S, of 1:30 is assumed for the calculations.

B30. Components of on-shore (P_{os}), long-shore (P_{ls}), and total, (P), energy-flux per foot of beach were calculated from the following equations:

$$P = \frac{\rho g H_b^2}{8} C \cos \alpha_b \qquad (6)$$

$$P_{os} = P \cos \alpha_b \qquad (7)$$

$$P_{ls} = P \sin \alpha_b \qquad (8)$$

Where ρ equals the density of water and g equals acceleration due to gravity.

Equations 6, 7, and 8 were solved for each wave condition and multiplied by their respective percent duration.

RESULTS OF LITTORAL DRIFT RATE CALCULATIONS

B31. The results of the calculations are given in Table B16 and Table B17 at the end of this appendix for each wave condition. The results include the breaker height, resultant energy-flux vector components, and the azimuth measured positively clockwise from north. Table B15 provides a list of symbols used in Tables B16 and B17. The resultant total energy-flux and its longshore and offshore components are summarized in Table B8. Table B9 summarizes the gross northward and gross southward energy-flux vectors. The positive flux is directed northward and the negative flux is directed southward along the shoreline. The breakdown shows the total flux in each direction, its longshore and offshore components, and its incident direction. The distribution of wave-energy fluxes is presented in Tables B10 and B11 and Figures B11 and B12.

TABLE B8. RESULTANT ENERGY FLUXES

Reach	Total Energy Flux	Longshore Flux	Onshore Flux	Ø
North	147.22	5.35	144.51	-74.1
South	115.89	5.48	113.06	-74.8

Note: The resultant direction of total energy flux in degrees of azimuth. Energy flux units of ft.-lbs./sec./ft. of beach.

TABLE B9. GROSS ENERGY-FLUX VECTORS

	P+	PLS+	POS+	AZ+	P-	PLS-	POS-	AZ-	PON
North Reach	95.27	15.27	93.99	-81.2	51.95	-9.91	50.52	-60.90	0.00
South Reach	85.08	14.01	83.58	-81.5	30.81	-8.52	29.48	-55.87	0.00

B32. Conversion of the net longshore energy flux to a potential longshore littoral transport rate was made by application of equation 4-10 of the Shore Protection Manual. The procedure is approximate and has been emperically derived from ocean beaches. The application to the Lakes is in questions, but the method should give an order-of-magnitude approximation. The results indicate that approximately 40,000 cubic yards of littoral drift pass to the north annually. This is approximately the rate at which bedload is delivered to the lakeshore from Cattaraugus Creek. The

TABLE B10

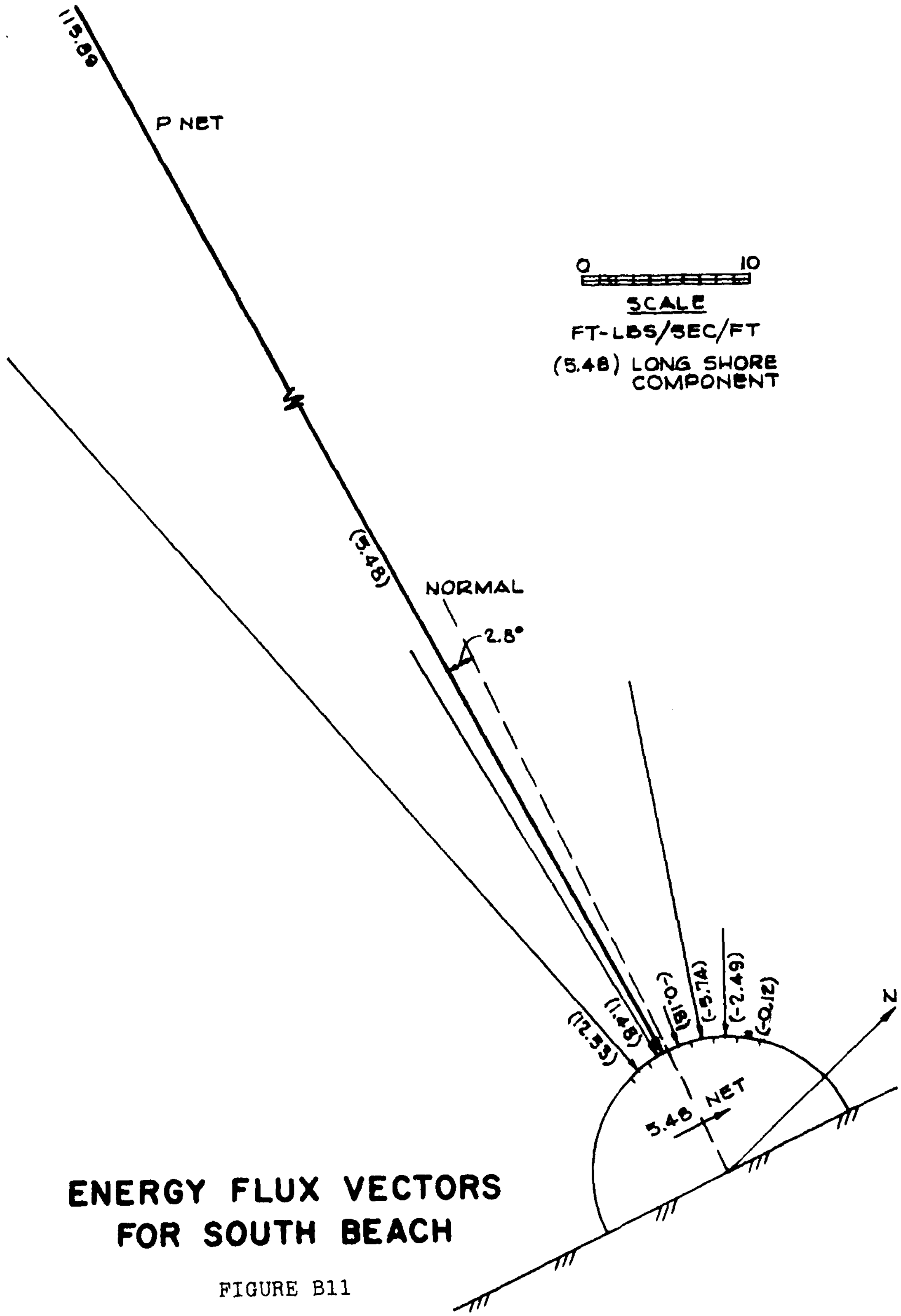
DISTRIBUTION OF ENERGY FLUX FOR SOUTH BEACH

AZ	TO AZ	P	PLS	POS
-162	-157	0.00	0.00	0.00
-157	-152	0.00	0.00	0.00
-152	-147	0.00	0.00	0.00
-147	-142	0.00	0.00	0.00
-142	-137	0.00	0.00	0.00
-137	-132	0.00	0.00	0.00
-132	-127	0.00	0.00	0.00
-127	-122	0.00	0.00	0.00
-122	-117	0.00	0.00	0.00
-117	-112	0.00	0.00	0.00
-112	-107	0.00	0.00	0.00
-107	-102	0.00	0.00	0.00
-102	-97	0.00	0.00	0.00
-97	-92	0.00	0.00	0.00
-92	-87	7.24	1.92	6.98
-87	-82	49.55	10.61	48.38
-82	-77	5.53	0.87	5.46
-77	-72	22.77	0.61	22.76
-72	-67	2.42	-0.18	2.42
-67	-62	0.01	-0.00	0.01
-62	-57	8.94	-2.07	8.69
-57	-52	12.79	-3.67	12.25
-52	-47	5.30	-2.00	4.90
-47	-42	1.12	-0.49	1.01
-42	-37	0.24	-0.12	0.21
-37	-32	0.00	0.00	0.00
-32	-27	0.00	0.00	0.00
-27	-22	0.00	0.00	0.00
-22	-17	0.00	0.00	0.00
-17	-12	0.00	0.00	0.00
-12	-7	0.00	0.00	0.00
-7	-2	0.00	0.00	0.00
-2	3	0.00	0.00	0.00
3	8	0.00	0.00	0.00
8	13	0.00	0.00	0.00
13	18	0.00	0.00	0.00

TABLE B11

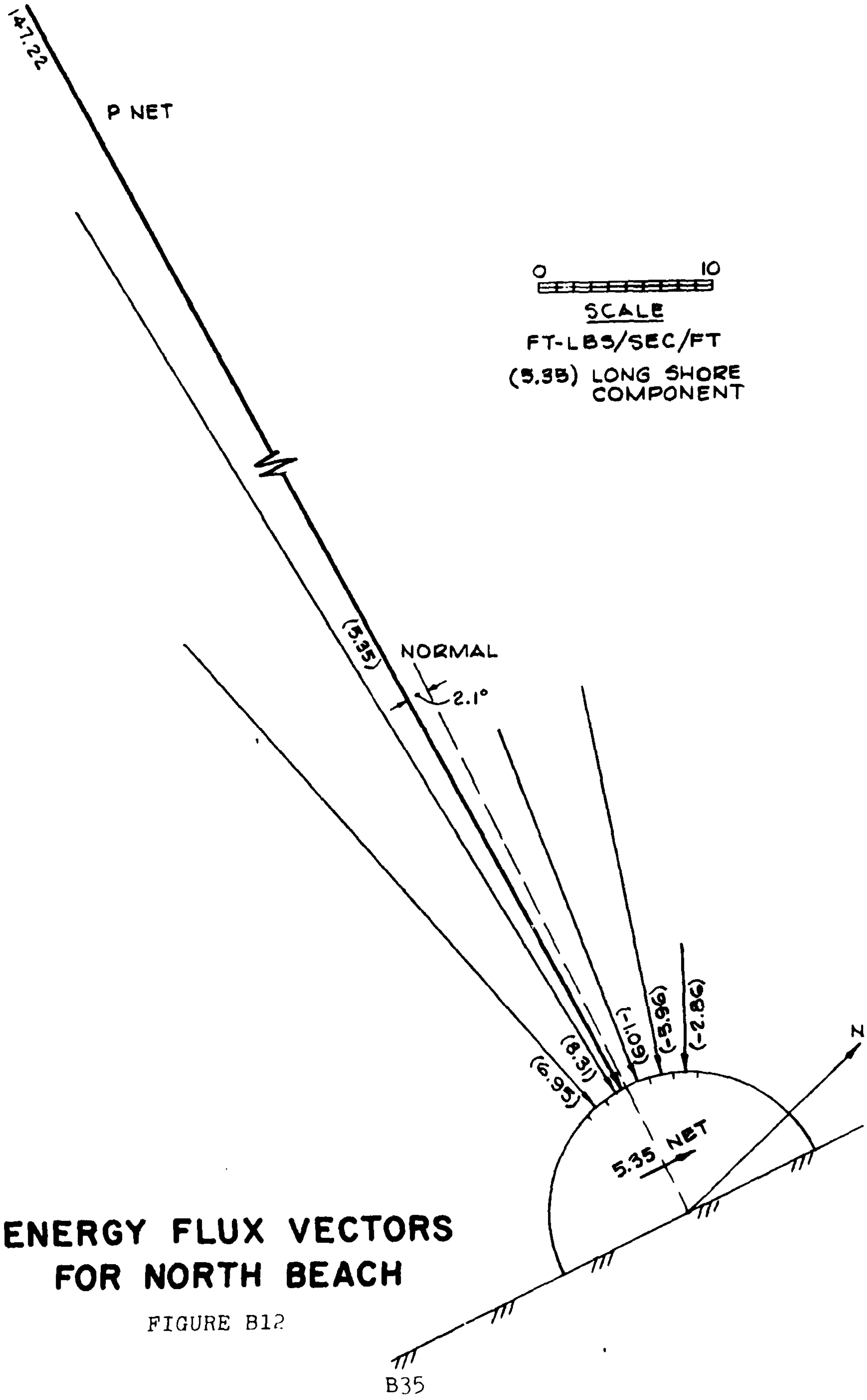
DISTRIBUTION OF ENERGY FLUX FOR NORTH BEACH

AZ	TO AZ	P	PLS	POS
-162	-157	0.00	0.00	0.00
-157	-152	0.00	0.00	0.00
-152	-147	0.00	0.00	0.00
-147	-142	0.00	0.00	0.00
-142	-137	0.00	0.00	0.00
-137	-132	0.00	0.00	0.00
-132	-127	0.00	0.00	0.00
-127	-122	0.00	0.00	0.00
-122	-117	0.00	0.00	0.00
-117	-112	0.00	0.00	0.00
-112	-107	0.00	0.00	0.00
-107	-102	0.00	0.00	0.00
-102	-97	0.00	0.00	0.00
-97	-92	0.00	0.00	0.00
-92	-87	0.00	0.00	0.00
-87	-82	35.71	6.95	35.03
-82	-77	58.46	8.23	57.87
-77	-72	1.10	0.08	1.09
-72	-67	21.81	-1.09	21.78
-67	-62	0.01	-0.00	0.01
-62	-57	11.17	-2.57	10.87
-57	-52	11.62	-3.39	11.11
-52	-47	6.43	-2.45	5.94
-47	-42	0.90	-0.41	0.81
-42	-37	0.00	0.00	0.00
-37	-32	0.00	0.00	0.00
-32	-27	0.00	0.00	0.00
-27	-22	0.00	0.00	0.00
-22	-17	0.00	0.00	0.00
-17	-12	0.00	0.00	0.00
-12	-7	0.00	0.00	0.00
-7	-2	0.00	0.00	0.00
-2	3	0.00	0.00	0.00
3	8	0.00	0.00	0.00
8	13	0.00	0.00	0.00
13	18	0.00	0.00	0.00



ENERGY FLUX VECTORS FOR SOUTH BEACH

FIGURE B11



ENERGY FLUX VECTORS FOR NORTH BEACH

FIGURE B12

net direction of approach is 2 to 3 degrees from the shoreline normal, toward the north. This indicates that the shoreline is relatively stable and in balance with the supply of littoral drift. Decrease in the littoral supply or changes induced by interruption of the coastline by the breakwaters should result in slow changes in orientation of the shoreline.

EFFECTS OF STRUCTURES ON LITTORAL TRANSPORT

GENERAL

B33. The littoral transport analysis indicated that the net potential rate of littoral transport at the project site is approximately 40,000 cubic yards per year to the northeast. The south breakwater will act as an impermeable groin impounding littoral drift on the south beach. This will effectively cut off the littoral drift supply to the downdrift beach to the northeast. Littoral drift is presently being supplied to the northeast beach from the Cattaraugus bedload and material which passes the river mouth from sources to the south. Construction of the south breakwater will reduce the existing supply from the updrift beach, and dredging of the channel will reduce the quantity of bedload entering the beach system. Construction of the breakwaters will reduce the effect of Cattaraugus Creek as a source to the southerly beaches during reversals in littoral transport to the south. These factors will tend to induce an erosion of the downdrift beach to the north. An analysis of the order of magnitude of accretion on the south beach and erosion on the north beach is made in the following section. The accretion and erosion of beaches to the south and north, respectively, are predicted by application of the Pelnard-Considère method. This method predicts the configuration of the fillets impounded or eroded at a groin, given the transport rate and angle of predominant wave attack.

SOUTH BEACH

B34. The potential littoral transport rate along the project site is estimated to be 40,000 cubic yards annually toward the north. The south beach is relatively stable. Minor erosion may be occurring. After construction of the breakwaters, Cattaraugus Creek will no longer distribute material on to the south beaches during northeasterly wave episodes. A littoral drift transport rate of 30,000 cubic yards per year has been used below to estimate the accretion of the fillet induced by construction of the south breakwater. The profiles in Figures B7 and B8 show the beach berm at +6 to +8 feet LWD. Assume that the beach forms a fillet to the -12 foot contour. Table B12 gives the results of the calculation for the fillet accretion as a function of distance south of the breakwater for 5-year time increments for 20 years. The beach is shown to accrete at a rate of 100 feet in the first 5 years on the south side of the south breakwater. The accretion fillet extends over 3000 feet downcoast. After 20 years, a 242-foot beach has accreted. The accretion extends to the southwest for about a mile in 20 years. Figure B13 shows the accretion growth from the 1975 beach line at lake level, +3.5 feet ± LWD.

TABLE B12. LONG-TERM ACCRETION - SOUTH BEACH
(Erosion in feet from existing shore)

	Stations along beach in feet:					
Years	0	1000	2000	3000	4000	5000
5	112	69	35	10	--	--
10	159	114	76	44	19	--
15	194	149	109	74	45	21
20	224	178	137	101	70	43

NORTH BEACH

B35. Aerial photographs indicate that the beach northeast of Cattaraugus Creek is in relative equilibrium. The north beach is more exposed to the larger, southwesterly waves than the southern beach. The change in lake level appears to have the greatest influence on the position of the shoreline. Under present conditions, littoral drift is supplied to the north beach material from the beach south of the creek and by the creek sediment load. The material on the north beach comprises a medium-to-coarse sand. After the breakwaters are constructed, the supply from the downdrift beach will be diminished. Small quantities will leak through the rubble breakwater and some will bypass the outer end of the breakwater. The amount bypassed will initially be low and will increase as the fillet on the south shore extends lakeward with time. The analysis of

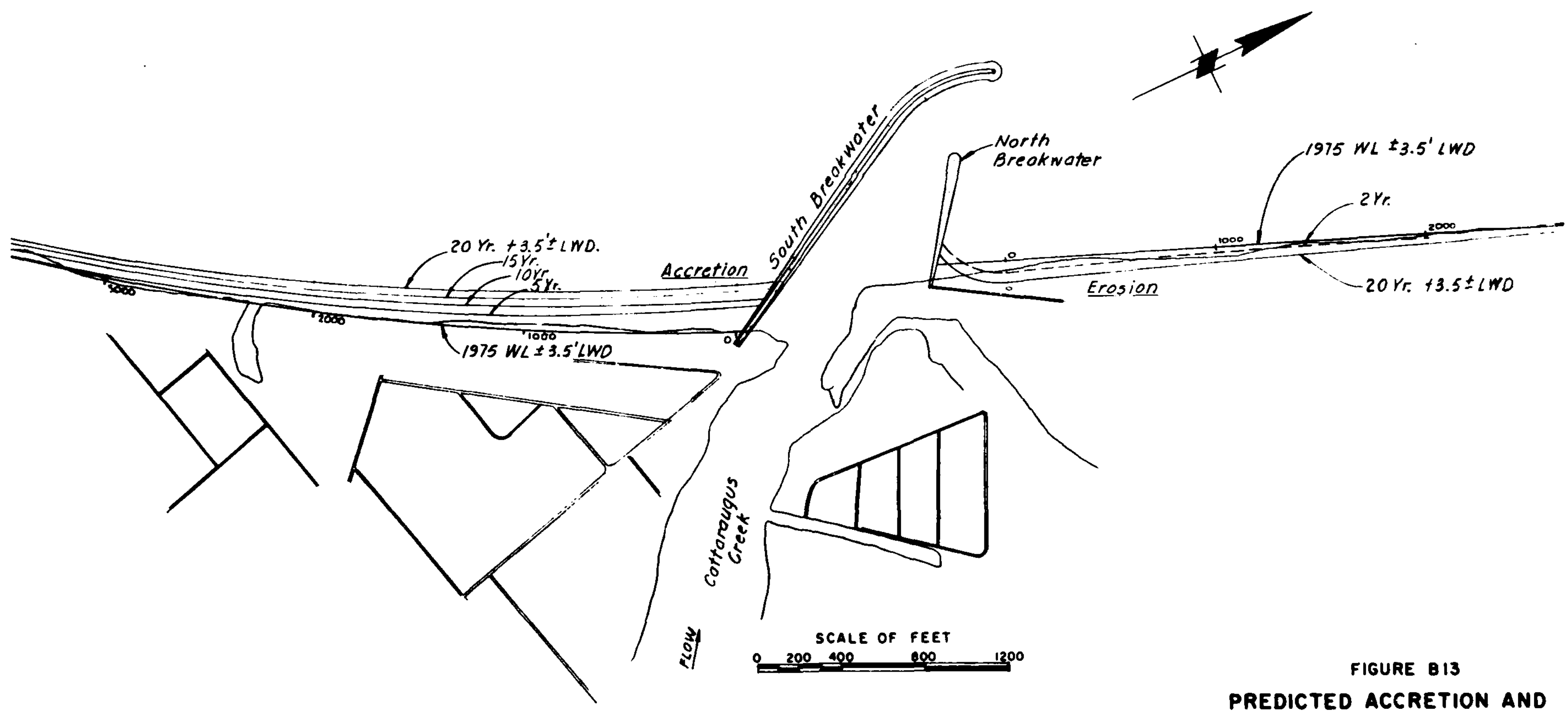


FIGURE B13

PREDICTED ACCRETION AND EROSION PATTERN FOR CATTARAUGUS CREEK

B38

beach erosion below assumed that 3,000 cubic yards bypass the project from the south to the north beach.

B36. The Cattaraugus bedload has been estimated to be 35,000 tons, or approximately 30,000 cubic yards, per year. A portion of this material is lost to the offshore and to channel filling. Assume the bedload and leakage from the south beach total 30,000 cubic yards per year. The potential drift rate is 40,000 cubic yards per year. This leaves a deficit of 10,000 yards per year, which should result in a long-term erosion. This figure is based on some rather broad assumptions and is intended only for an order-of-magnitude analysis. Figure B13 shows the 20-year erosion pattern on the downdrift beach to the north. This erosion indicates a maximum of 100 feet at the north breakwater. Half of this should occur within the first five years. Table B13 summarizes the erosion for intervening years and downcoast erosion.

TABLE B13. LONG-TERM EROSION - NORTH BEACH
(Erosion in feet from existing shore)

Years	Stations along beach in feet: 0	1000	2000	3000	4000
5	54	23	3	--	--
10	76	43	19	2	--
15	93	60	33	13	--
20	107	73	46	24	7

B37. The above analysis is the long-term effect. The sediment derived from the bedload will most likely be delivered to the beach during low or declining lake levels and during major events. Although an average bedload of 35,000 tons was estimated, it is possible that during a typical year only 5,000 tons may be transported into the lake. The larger volume of material will be transported during less frequent major events. Because of this, allowance should be made for a greater deficit of material on a short-term basis. Assume a deficit of 30,000 cubic yards per year. Table B14 gives the erosion offsets for stations to the north. The shoreline after two years of short-term erosion is plotted in Figure B13. This indicates the order of magnitude of erosion in the event maintenance dredging is not conducted and no major events occur.

The analysis indicates approximately 100 feet of erosion may occur at the north breakwater in two years of low sediment discharge. Due to the possibility of long-term erosion with a short-term erosion superimposed during the life of the structure, the eroded beach profile should be taken into account in design of the sand berm to protect from toe scour.

TABLE B14. SHORT-TERM EROSION - NORTH BEACH
(Erosion in feet from existing shore)

Years	Stations along beach in feet: 0	1000
1	41	13
2	58	27
3	71	40
4	82	50
5	92	60

APPLICATION TO DESIGN AND MAINTENANCE

B38. The erosion rates and shoreline positions predicted above are general estimates. The shoreline near the north breakwater will be modified due to the diffraction of waves about the breakwaters. This effect will be most evident in the erosion zone immediately to the north. Figure B13 shows the shape the shoreline is likely to assume along the north beach. The maximum zone of erosion is shifted from the breakwater to the north to coincide with the wave shadow afforded by the south breakwater. The beach adjacent to the north breakwater will tend to align with the northerly and diffracted wave crests.

B39. The analysis predicts an accretion on the south beach and an erosion on the north beach. The difference in rates is attributed to the Cattaraugus bedload which nourishes the north beach. The breakwater system is designed to deposit the bedload into the north beach littoral zone. Waves and current are to carry this material shoreward. A shoal may form in the vicinity of the breakwater and creek mouth, and material may not be transported to shore as efficiently as calculated. Upstream gravel operations deprive the system of a significant portion of the bedload. Channel dredging will trap coarser bedload material; therefore, the sediment delivered to the beach will comprise a finer grain size distribution than under present conditions. As a consequence to the aforementioned changes, less beach-size material may be transported to the lake. An allowance for periodic maintenance should be made to dredge the predicted shoal and channel material and deposit this material on the downdrift beach.

B40. The accretion on the south beach immediately south of the south breakwater should result in a long-term benefit to property owners by the accretion fillet formed by the south breakwater. The widened beach should result in bathing beach benefits, also. The erosion of the north beach should tend to counter this benefit to a degree. Material supplied to the southern beaches during reversals in littoral drift will be terminated by construction of the breakwaters. A long-term erosion may occur on the south beach as the beach attains a new equilibrium. The south beach may require some nourishment at a point approximately 3/4-miles to the south of the project site.

EFFECT OF STRUCTURES ON LITTORAL SOURCE

B41. Cattaraugus Creek is a source of littoral drift. Under present conditions, the sediment load is carried into the lake. A large, submerged deltaic feature has formed offshore of the project site. This feature comprises a layer of 2 to 10 feet of fluvial outwash of loosely compacted fine sands. Coarser material is deposited near shore during a flood and is transported by waves and currents to form the beach by building sand bars which eventually migrate onto shore. The net direction of drift is toward the northeast. However, portions of the material may be distributed on the south beach, temporarily supplying this reach with sediment.

B42. Construction of the breakwaters will alter the present system. Material will be injected 800 feet further into the lake. The fines will be transported offshore to form a delta; however, not in the same location as the existing delta. A new delta would tend to form further toward the north. During lower lake levels, the old delta would tend to flatten in slope under wave grading. The coarser material will be deposited in the vicinity of the harbor entrance. Shoals may develop and at times become hazards to navigation; however, stream flow and wave action should keep the entrance free from obstruction. The coarser material, in time, should enter the beach system to the north as littoral drift. Since the outlet is further offshore than under existing conditions, a greater portion of material is anticipated to be lost offshore due to the decreased ability of the waves to transport the material. The resultant decrease in littoral supply from the creek source, coupled with the interception of most of the littoral drift from the south beach by the south breakwater, should result in erosion of the north beach. The long-term erosion should be minor, providing that required maintenance dredging in the creek bed and mouth will be deposited on the north beach. As previously mentioned, the littoral supply from updrift beaches is estimated to be minimal, and the littoral budget of the north beach is derived primarily from the Cattaraugus Creek source. The corollary of the foregoing argument is that disposal of maintenance dredge spoil elsewhere than on the north beach will result in erosion of that beach. The required total maintenance dredging is estimated at 10,000 to 20,000 cubic yards per year, which should be adequate nourishment for the north beach. The actual quantity will vary with lake stage over a long term and will vary appreciably with the intensity of seasonal flood flows.

TABLE B15. LIST OF SYMBOLS FOR TABLES B16 AND B17

D - Direction of wave approach, where:

1 = west-southwest

2 = west

3 = north-northwest

4 = north

5 = north-northeast

6 = northeast

AZ - Azimuth° from true north, measured positive clockwise.

T - Wave period in seconds.

HB - Breaker height in feet.

AB - Azimuth of wave breaking angle.

P - Total component of longshore energy flux.

PLS - Longshore component of energy flux.

POS - Onshore component of energy flux.

AO - Azimuth of hypothetical deep-water wave direction.

TABLE B16. LITTORAL TRANSPORT ANALYSIS FOR NORTH REACH
(Sheet 1 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
1	-82.0	5.0	0.53	-74.54	0.0031	0.0001	0.0031	-86.38
2	-86.5	2.0	0.49	-79.11	0.0169	0.0021	0.0168	-86.50
2	-86.5	3.0	0.63	-77.13	0.0188	0.0017	0.0188	-87.02
3	-69.0	2.0	0.50	-70.50	0.0156	-0.0004	0.0156	-69.00
3	-69.0	3.0	0.65	-70.91	0.0051	-0.0001	0.0051	-68.89
4	-50.0	2.0	0.47	-61.56	0.0171	-0.0031	0.0168	-50.00
4	-50.0	3.0	0.60	-64.48	0.0083	-0.0011	0.0083	-49.19
5	-31.5	2.0	0.41	-54.74	0.0107	-0.0032	0.0102	-31.50
5	-31.5	3.0	0.53	-59.66	0.0091	-0.0019	0.0089	-29.76
6	-18.5	2.0	0.27	-54.42	0.0027	-0.0008	0.0026	-18.50
6	-18.5	3.0	0.35	-59.52	0.0032	-0.0007	0.0031	-15.69
1	-82.0	5.0	1.21	-75.81	0.3134	0.0208	0.3128	-86.38
1	-82.0	6.0	1.34	-75.88	0.0311	0.0021	0.0310	-89.01
2	-86.5	2.0	1.12	-82.11	0.1061	0.0186	0.1045	-86.50
2	-86.5	3.0	1.44	-79.55	2.1469	0.2822	2.1283	-87.02
2	-85.0	4.0	1.74	-78.28	1.5711	0.1717	1.5616	-87.65
3	-69.0	2.0	1.15	-69.87	0.0574	-0.0021	0.0574	-69.00
3	-69.0	3.0	1.48	-70.41	1.0402	-0.0289	1.0398	-68.89
3	-68.0	4.0	1.74	-70.06	0.2935	-0.0100	0.2933	-67.20
4	-50.0	2.0	1.07	-57.05	0.0620	-0.0160	0.0599	-50.00
4	-50.0	3.0	1.38	-60.90	1.8602	-0.3581	1.8254	-49.19
4	-48.0	4.0	1.61	-61.02	0.0946	-0.0180	0.0929	-42.81
5	-31.5	2.0	0.94	-46.81	0.0324	-0.0138	0.0293	-31.50
5	-31.5	3.0	1.22	-53.61	1.4847	-0.4683	1.4089	-29.76

TABLE B16. LITTORAL TRANSPORT ANALYSIS FOR NORTH REACH
(Sheet 2 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
5	-31.5	4.0	1.44	-55.22	0.1405	-0.0406	0.1346	-20.85
6	-18.5	2.0	0.62	-45.82	0.0233	-0.0103	0.0209	-18.50
6	-18.5	3.0	0.80	-53.26	0.3845	-0.1236	0.3642	-15.69
6	-18.5	4.0	0.95	-55.00	0.0125	-0.0036	0.0119	2.58
1	-82.0	5.0	1.78	-76.59	0.7489	0.0599	0.7465	-86.38
2	-86.5	3.0	2.12	-80.94	3.9024	0.6068	3.8549	-87.02
2	-85.0	4.0	2.55	-79.50	4.6227	0.6034	4.5832	-87.65
2	-85.0	5.0	2.89	-79.51	0.6211	0.0812	0.6157	-90.76
3	-69.0	3.0	2.18	-70.12	0.7838	-0.0258	0.7834	-68.89
3	-68.0	4.0	2.56	-69.68	1.8091	-0.0733	1.8076	-67.20
4	-50.0	3.0	2.02	-58.82	0.9566	-0.2181	0.9314	-49.19
4	-48.0	4.0	2.36	-58.84	4.8294	-1.0996	4.7026	-42.81
5	-31.5	3.0	1.79	-50.00	0.9548	-0.3576	0.8853	-29.76
5	-31.5	4.0	2.11	-51.79	1.7741	-0.6130	1.6648	-20.85
6	-18.5	3.0	1.18	-49.40	0.2412	-0.0927	0.2226	-15.69
6	-18.5	4.0	1.39	-51.43	0.2207	-0.0776	0.2066	2.58
1	-82.0	5.0	2.29	-77.18	1.0490	0.0947	1.0447	-86.38
1	-82.0	6.0	2.53	-77.29	0.3014	0.0278	0.3001	-89.01
2	-86.5	3.0	2.73	-81.94	0.4992	0.0862	0.4917	-87.02
2	-85.0	4.0	3.28	-80.41	9.6610	1.4123	9.5572	-87.65
2	-85.0	5.0	3.72	-80.45	0.7696	0.1131	0.7612	-90.76
3	-69.0	3.0	2.80	-69.91	0.5401	-0.0197	0.5397	-68.89

TABLE B16. LITTORAL TRANSPORT ANALYSIS FOR NORTH REACH
(Sheet 3 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
3	-68.0	4.0	3.29	-69.40	4.1942	-0.1902	4.1899	-67.20
3	-68.0	5.0	3.73	-69.39	0.3898	-0.0178	0.3894	-66.28
4	-48.0	4.0	3.04	-57.21	3.3395	-0.8524	3.2288	-42.81
5	-31.5	3.0	2.30	-47.33	0.1016	-0.0424	0.0923	-29.76
5	-31.5	4.0	2.72	-49.18	1.6201	-0.6284	1.4932	-20.85
1	-82.0	5.0	2.76	-77.67	0.7426	0.0733	0.7390	-86.38
1	-82.0	6.0	3.06	-77.79	1.4419	0.1454	1.4345	-89.01
2	-85.0	4.0	3.97	-81.13	0.8720	0.1384	0.8609	-87.65
2	-85.0	5.0	4.50	-81.22	7.0162	1.1241	6.9256	-90.76
2	-85.0	6.0	4.97	-81.46	3.9662	0.6521	3.9122	-94.27
3	-68.0	4.0	3.97	-69.18	1.7697	-0.0871	1.7675	-67.20
4	-48.0	4.0	3.67	-55.90	4.5558	-1.2636	4.3770	-42.81
4	-48.0	5.0	4.16	-55.77	1.4680	-0.4104	1.4095	-36.44
5	-31.5	4.0	3.28	-47.04	1.5164	-0.6399	1.3748	-20.85
1	-82.0	5.0	3.21	-78.08	1.6139	0.1710	1.6048	-86.38
1	-82.0	6.0	3.55	-78.22	1.0458	0.1133	1.0397	-89.01
2	-85.0	4.0	4.61	-81.74	1.8801	0.3179	1.8530	-87.65
2	-85.0	5.0	5.23	-81.87	2.6407	0.4526	2.6016	-90.76
2	-85.0	6.0	5.78	-82.15	1.1467	0.2021	[illegible]	-94.27
3	-68.0	5.0	5.23	-68.95	2.6850	-0.1428	2.6812	-66.28
4	-48.0	4.0	4.26	-54.79	0.5022	-0.1486	0.4797	-42.81
4	-48.0	5.0	4.83	-54.59	2.1102	-0.6314	2.0135	-36.44
5	-31.5	4.0	3.82	-45.22	0.7182	-0.3237	0.6412	-20.85
6	-18.5	4.0	2.51	-44.41	0.1284	-0.0595	0.1138	2.58

TABLE B16. LITTORAL TRANSPORT ANALYSIS FOR NORTH REACH
(Sheet 4 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
1	-82.0	5.0	3.64	-78.45	1.4641	0.1644	1.4548	-86.38
1	-82.0	6.0	4.03	-78.60	0.4749	0.0546	0.4718	-89.01
2	-85.0	4.0	5.22	-82.25	3.3851	0.6026	3.3310	-87.65
2	-85.0	5.0	5.92	-82.43	9.5431	1.7283	9.3853	-90.76
2	-85.0	6.0	6.55	-82.76	1.5569	0.2906	1.5295	-94.27
3	-68.0	4.0	5.23	-68.83	0.8613	-0.0476	0.8600	-67.20
3	-68.0	5.0	5.93	-68.78	1.2148	-0.0683	1.2129	-66.28
4	-48.0	5.0	5.48	-53.56	0.9499	-0.3005	0.9012	-36.44
1	-82.0	5.0	4.05	-78.78	1.4288	0.1686	1.4188	-86.38
1	-82.0	6.0	4.48	-78.95	1.2373	0.1496	1.2282	-89.01
1	-82.0	7.0	4.87	-79.15	0.7673	0.0955	0.7613	-91.80
2	-85.0	5.0	6.60	-82.94	1.5461	0.2933	1.5181	-90.76
3	-68.0	5.0	6.60	-68.63	1.5769	-0.0928	1.5742	-66.28
1	-82.0	7.0	5.35	-79.47	0.9672	0.1258	0.9590	-91.80
2	-85.0	5.0	7.24	-83.39	1.9383	0.3827	1.9001	-90.76
2	-85.0	6.0	8.01	-83.79	5.0774	1.0370	4.9703	-94.27
3	-68.0	5.0	7.25	-68.49	1.9796	-0.1213	1.9759	-66.28
3	-68.0	6.0	8.02	-68.37	2.5963	-0.1645	2.5910	-65.25
1	-82.0	7.0	5.82	-79.78	0.5940	0.0804	0.5885	-91.80
2	-85.0	5.0	7.87	-83.79	2.3678	0.4840	2.3178	-90.76
2	-85.0	6.0	8.71	-84.23	6.2131	1.3164	6.0720	-94.27
1	-82.0	7.0	6.27	-80.06	4.2867	0.6008	4.2444	-91.80
2	-85.0	5.0	8.49	-84.17	2.8333	0.5972	2.7697	-90.76
1	-82.0	7.0	6.72	-80.32	0.8449	0.1222	0.8360	-91.80

TABLE B17 LITTORAL TRANSPORT ANALYSIS FOR SOUTH REACH
(Sheet 1 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
2	-91.5	2.0	0.49	-81.52	0.0170	0.0028	0.0168	-91.50
2	-91.5	3.0	0.64	-78.87	0.0190	0.0023	0.0189	-92.21
3	-65.0	2.0	0.50	-68.51	0.0155	-0.0009	0.0155	-65.00
3	-65.0	3.0	0.65	-69.47	0.0050	-0.0002	0.0050	-64.75
4	-43.0	2.0	0.45	-58.63	0.0157	-0.0036	0.0153	-43.00
4	-43.0	3.0	0.59	-62.39	0.0077	-0.0013	0.0076	-41.88
5	-34.0	2.0	0.42	-55.62	0.0109	-0.0031	0.0104	-34.00
5	-34.0	3.0	0.54	-60.28	0.0092	-0.0019	0.0090	-32.42
6	-14.0	2.0	0.33	-51.49	0.0044	-0.0015	0.0041	-14.00
6	-14.0	3.0	0.43	-57.44	0.0052	-0.0013	0.0051	-10.63
2	-91.5	2.0	1.12	-85.57	0.1061	0.0249	0.1031	-91.50
2	-91.5	3.0	1.45	-82.12	2.1591	0.3792	2.1255	-92.21
2	-89.0	4.0	1.60	-79.84	1.2658	0.1727	1.2540	-92.52
3	-65.0	2.0	1.15	-67.05	0.0569	-0.0049	0.0567	-65.00
3	-65.0	3.0	1.48	-68.29	1.0326	-0.0668	1.0305	-64.75
3	-74.0	4.0	1.86	-73.00	0.3455	0.0060	0.3454	-74.40
4	-43.0	2.0	1.04	-52.74	0.0564	-0.0186	0.0532	-43.00
4	-43.0	3.0	1.34	-57.77	1.7075	-0.4197	1.6552	-41.88
4	-48.5	4.0	1.52	-61.53	0.0823	-0.0150	0.0809	-43.43
5	-34.0	2.0	0.95	-48.16	0.0331	-0.0134	0.0303	-34.00
5	-34.0	3.0	1.22	-54.56	1.5104	-0.4526	1.4410	-32.42

TABLE B17. LITTORAL TRANSPORT ANALYSIS FOR SOUTH REACH
(Sheet 2 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
5	-34.0	4.0	1.45	-56.08	0.1428	-0.0392	0.1374	-24.41
6	-14.0	2.0	0.76	-41.48	0.0365	-0.0185	0.0315	-14.00
6	-14.0	3.0	0.98	-50.12	0.6198	-0.2310	0.5752	-10.63
6	-14.0	4.0	1.16	-52.88	0.0203	-0.0066	0.0192	6.52
2	-91.5	3.0	2.13	-83.99	3.9127	0.8129	3.8273	-92.21
2	-89.0	4.0	2.34	-81.39	3.7236	0.6073	3.6737	-92.52
2	-89.0	5.0	2.65	-81.39	0.4997	0.0815	0.4930	-96.71
3	-65.0	3.0	2.17	-67.61	0.7776	-0.0595	0.7753	-64.75
3	-74.0	4.0	2.73	-73.20	2.1281	0.0444	2.1276	-74.40
4	-43.0	3.0	1.96	-55.07	0.8740	-0.2546	0.8361	-41.88
4	-48.5	4.0	2.23	-59.44	4.2051	-0.9143	4.1045	-43.43
5	-34.0	3.0	1.79	-51.16	0.9737	-0.3465	0.9100	-32.42
5	-34.0	4.0	2.12	-52.84	1.8070	-0.5932	1.7068	-24.41
6	-14.0	3.0	1.44	-45.62	0.3838	-0.1705	0.3438	-10.63
6	-14.0	4.0	1.70	-48.86	0.3568	-0.1402	0.3281	6.52
2	-91.5	3.0	2.74	-85.33	0.4993	0.1151	0.4858	-92.21
2	-89.0	4.0	3.01	-82.54	7.7803	1.4228	7.6491	-92.52
2	-89.0	5.0	3.42	-82.58	0.6188	0.1136	0.6083	-96.71
3	-65.0	3.0	2.79	-67.13	0.5356	-0.0454	0.5336	-64.75

TABLE B17. LITTORAL TRANSPORT ANALYSIS FOR SOUTH REACH
(Sheet 3 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
3	-74.0	4.0	3.51	-73.34	4.9300	0.1152	4.9286	-74.40
3	-74.0	5.0	3.98	-73.35	0.4588	0.0108	0.4587	-74.86
4	-48.5	4.0	2.87	-57.88	2.9116	-0.7101	2.8236	-43.43
5	-34.0	3.0	2.31	-48.65	0.1038	-0.0412	0.0953	-32.42
5	-34.0	4.0	2.73	-50.38	1.6533	-0.6092	1.5370	-24.41
2	-89.0	4.0	3.64	-83.46	0.7021	0.1395	0.6881	-92.52
2	-89.0	5.0	4.13	-83.55	5.6384	1.1291	5.5242	-96.71
2	-89.0	6.0	4.56	-83.85	3.1828	0.6534	3.1150	-101.51
3	-74.0	4.0	4.24	-73.45	2.0785	0.0527	2.0779	-74.40
4	-48.5	4.0	3.46	-56.62	3.9768	-1.0546	3.8344	-43.43
4	-48.5	5.0	3.93	-56.52	1.2801	-0.3417	1.2337	-37.24
5	-34.0	4.0	3.30	-48.37	1.5504	-0.6215	1.4204	-24.41
2	-89.0	4.0	4.23	-84.24	1.5138	0.3209	1.4794	-92.52
2	-89.0	5.0	4.80	-84.38	2.1211	0.4547	2.0718	-96.71
2	-89.0	6.0	5.30	-84.72	0.9195	0.2025	0.8969	-101.51
3	-74.0	5.0	5.59	-73.57	3.1574	0.0865	3.1562	-74.86
4	-48.5	4.0	4.02	-55.56	0.4389	-0.1242	0.4209	-43.43
4	-48.5	5.0	4.56	-55.39	1.8419	-0.5266	1.7650	-37.24
5	-34.0	4.0	3.83	-46.65	0.7356	-0.3149	0.6648	-24.41
6	-14.0	4.0	3.07	-40.96	0.2034	-0.1049	0.1742	6.52

TABLE B17. LITTORAL TRANSPORT ANALYSIS FOR SOUTH REACH
(Sheet 4 of 4)

D	AZ	T	HB	AB	P	PLS	POS	AO
2	-89.0	4.0	4.79	-84.91	2.7255	0.6089	2.6567	-92.52
2	-89.0	5.0	5.44	-85.10	7.6621	1.7367	7.4627	-96.71
2	-89.0	6.0	6.01	-85.49	1.2475	0.2910	1.2131	-101.51
3	-74.0	4.0	5.59	-73.63	1.0102	0.0287	1.0098	-74.40
3	-74.0	5.0	6.34	-73.66	1.4280	0.0413	1.4274	-74.86
4	-48.5	5.0	5.17	-54.40	0.8299	-0.2510	0.7911	-37.24
2	-89.0	5.0	6.05	-85.74	1.2409	0.2948	1.2054	-96.71
3	-74.0	5.0	7.05	-73.74	1.8528	0.0561	1.8520	-74.86
2	-89.0	5.0	6.65	-86.32	1.5551	0.3847	1.5067	-96.71
2	-89.0	6.0	7.35	-86.80	4.0633	1.0381	3.9284	-101.51
3	-74.0	5.0	7.75	-73.81	2.3250	0.0732	2.3239	-74.86
3	-74.0	6.0	8.57	-73.87	3.0541	0.0997	3.0524	-75.37
2	-89.0	5.0	7.23	-86.85	1.8991	0.4867	1.8356	-96.71
2	-89.0	6.0	7.99	-87.38	4.9692	1.3176	4.7913	-101.51
2	-89.0	5.0	7.79	-87.34	2.2718	0.6008	2.1909	-96.71

APPENDIX C

GEOLOGY, SOILS AND CONSTRUCTION MATERIALS

APPENDIX C
GEOLOGY, SOILS, AND CONSTRUCTION MATERIALS
FOR
CATTARAUGUS CREEK HARBOR,
NEW YORK

CONTENTS

CONTENTS
(Continued)

LIST OF TABLES

CONTENTS
(Continued)

LIST OF TABLES
(Continued)

LIST OF FIGURES

PLATES

PLATES
(Continued)

REGIONAL SOILS AND GEOLOGY

REGIONAL GEOMORPHOLOGY

C1. General terrain features in the Great Lakes region were formed by glacial processes and concatenate shoreline and stream processes. During the Pleistocene Glacial Epoch, the region was covered by glacial lobes which encroached from centers in what is now Canada. The glacial movement was guided and finally terminated by massive terrain features. These features, in turn, were modified, transformed, and re-sculpted by the glacial movement.

C2. Previous to the most extensive glacial encroachment, the overall relief of terrain features had been lessened by the filling of deep valley and basin features with thousands of years of snow and ice accumulation. This blanket of ice and snow acted as a shear buffer during the subsequent glacial movement and, as a result, the glacial scour had a more severe effect on the higher, nearshore regions of existing lake basins and on the highlands partioning the valleys and basins.

C3. The glacial action and the associated stages of the Erie region glacial lake gave rise to the present composition of the Lake Erie basin and shoreline. Most prominent of the existing topographic features are the lowland that is now the basin of Lake Erie and the 1000-foot escarpment that now borders it to the south in New York.

PHYSIOGRAPHY

C4. The project site is situated on the southeastern slope of Lake Erie approximately 35 miles southwest of Buffalo, New York. "A portion of the Cattaraugus Indian Reservation lies in the westerly part of the Town of Brant, Erie County, and occupies the entire northerly side of Cattaraugus Creek within the study area. The 1,700 acre reservation is inhabited by Senecas. The southerly side of the creek is in the Town of Hanover, Chautauqua County, and about four and one-half miles of the town borders the creek.[1]

[1]Paragraphs C4 through C7 excerpted from "Environmental Statement, Cattaraugus Creek Harbor, N.Y.," March, 1975, U. S. Army Corps of Engineers, Buffalo District.

C5. "The northern portion of the region containing the project site is on the Erie Lake Plain. The plain varies from 2 to 4 miles wide. It is relatively flat representing the floor of glacial lakes ancestral to Lake Erie. The plain slopes to the shores of Lake Erie and the gradient in this area is so low that drainage of surface water is a frequent problem. Immediately in back (south) of the Lake Plain is an escarpment which is the most distinctive topographical feature of the region. The escarpment appears from the plain as a solid wall of hills which make a sharp break between the lowlands of the plain and Allegheny Plateau in the hinterland. The elevation of the escarpment changes from 800 to 900 feet at the bottom to about 1,200 to 1,400 feet at the top of the escarpment. Much of the escarpment is comprised of long smooth slopes, and is also broken by canyons and cliffs. Parts of the escarpment are covered by deep layers of glacial till, valley moraine, the surface of which appears as a jumble of small, steep hills, bogs, ponds, and rolling terrain.

BEDROCK GEOLOGY

C6. "Underlying the Lake Plain are flat bedded strata of shales and siltstones. These rocks are impermeable to the downward percolation of water. The bedrock is covered by a variety of till (glacial drift consisting of caly, sand, gravel and boulders). The soil mantle is quite thick. The bedrock beneath the project site consists of Angola Shale and Hanover Shale of the Late Devonian (Chautauquan) age. The Angola Shale Member is included in the West Falls Formation and is exposed along the shore of Lake Erie. This shale formation is 220-330 feet thick and characteristically consists of medium light-gray to light-gray shale containing a little black shale, a few thin siltstones and many calcareous nodules of various sizes. The Hanover shale member is in the Java formation and consists of about 90 feet of gray to greenish-gray shale with occasional black shale bands, gray silty shale, then limestone beds and many zones of calcareous nodules. These nodules occur in a great variety of shapes and vary from a half inch to three feet in diameter. Prominent outcrops occur at Cattaraugus Creek from its mouth at Irving upstream to Versailles.

LOCAL SOILS AND GEOLOGY

GENERAL CATTARAUGUS CREEK BASIN

C7. "Cattaraugus Creek drains several tributary branches of Zoar Valley (the main branch arises 18.6 miles (30 km) further east near Arcade, NY), and passes through agricultural and wooded land. The creek is 70 miles long and drains an area of about 554 square miles on the south shore of Lake Erie. The creek crosses the Cattaraugus Indian Reservation and passes Versailles. It then runs through Irving on the lake plain and enters Lake Erie at Sunset Bay. Over the years, Cattaraugus Creek has changed course. An oxbow has formed just south of the New York State Thruway on the Cattaraugus Indian Reservation. The creek near its mouth in its present alluvial flood plain has a relatively gentle flow owing to the low gradient, and in consequence diminished strength of current. It is therefore easily turned by obstacles and tends to wander in the plain in a series of meanders. Oxbows often create marshes and finally perhaps low meadows."

C8. Cattaraugus Creek follows the run of the Ancient Allegheny Valley from Gowanda, New York, down to the Cattaraugus Embayment on the Lake Erie shoreline. "In many places, this valley is filled with glacial deposits which have been compacted by thousands of feet or overriding ice . . . . Records of wells drilled through the glacial deposits indicate that the elevation of bedrock is between 200 and 300 feet below sea level. A gravity survey along the beach places the bedrock at the present mouth of Cattaraugus Creek at about 275 feet below the lake."[2]

C9. The project is centered about the mouth of the Cattaraugus Creek. Project features extend approximately 1.5 miles east and upstream of the creek mouth and approximately 0.3 miles west into Lake Erie. The area is occupied by many cottages along both sides of the creek.

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[2]"Littoral Processes and Sedimentation in the Cattaraugus Embayment, N.Y.," 1974, U. S. Army Corps of Engineers, Buffalo District. Appendix E.

SITE GEOLOGY

C10. The transgression of marine, hypersaline and fresh waters of Silurian, Devonian, later Pleistocene Epoch and continuing to the present time deposited sediments which were later compressed into the bedrock deeply underlying the site area. Seven major soil units were encountered within the project area during the 1975 subsurface exploration program. They were encountered in the following general sequence beginning with ground surface:

Alluvial Deposits
Glacial Outwash Deposits
Glacial Till Deposits (Upper)
Glacio-fluvial Deposits
Glacial Lake Deposits
Glacial Till Deposits (Lower)
Bedrock

One or more of these major groups may be missing at any particular location. The following is a brief discussion of the various strata encountered, starting in reverse order to reflect their sequence of deposition.

a. Bedrock: Bedrock was encountered only at the extreme easterly portion of site below El. 558.7 IGLD. It is identified as an amorphous-to-fine-grained gray shale with interbedded siltstone. The rock is classified as the Angola Shale member of the West Falls Formation.

b. Glacial Till (Lower): During the last continental glaciation, ground moraine till was deposited directly over the bedrock surface. The till is a heterogeneous mixture of silt, sand, clay, gravel and boulders. At the site, a till-like material was encountered over the bedrock consisting of a medium-compact to very-compact gray silty fine sand.

c. Glacial Lake Deposits: The glacial lake deposits at the site consist of medium-stiff to stiff, gray varved, silty clays to clayey silts, with trace amounts of fine sand in lenses. In north central North America, the last glacial period, the Wisconsin, was one of general deglaciation and re-expansion of the Laurentide Ice Sheet at irregular intervals. This produced a series of glacial lakes which geographically coincided with the approximate present location of Lake Erie. The varved silty clay deposits encountered at the site are characteristic of the regular deposition of clay during the calm winter months and fine sand and silt during the summer months. One varve typically consists of a 1/4- to 3/8-inch thick clay layer and a 1/8-inch silt and/or fine sand layer.

d. Glacio-fluvial Deposits: The glacio-fluvial deposits range from very stiff, gray, slightly plastic silts with varying amounts of fine sand and clay which overlie the glacial lake deposits to an upper-compact to very-compact gray silty fine sand to fine sandy silt. The origin of these soils stems from the melting of the continental ice sheets and the resulting stream formation.

e. Glacial Till (Upper): Upper glacial till was encountered above the glacio-fluvial deposits. This unsorted, well-bonded soil unit was deposited as a result of the last re-advancing ice mass to cover the site area, and was encountered only within the confines of Lake Erie. The presence of this layer gives geologic evidence that the underlying silt and clay deposits were subject to loading in excess of present overburden pressures. The absence of this stratum from the upper creek area is due probably to erosion or perhaps it was never deposited there. The test borings indicate that the upper glacial till consists of medium-compact to very-compact, well-bonded, gray, coarse-to-fine sands to sandy coarse-to-fine gravels, with varying amounts of silts, gravels, and cobbles.

f. Glacial Outwash Deposits: The glacial outwash deposits encountered at the site range from loose to very-compact gray, gravelly coarse-to-fine sands to sandy coarse-to-fine gravels, with varying amounts of silt, cobbles, and isolated pockets of silt and fine sand. The particle sizes of these soils indicate that they were deposited as the melting ice created streams with varying load capacities.

g. Alluvial Deposits: The alluvial deposits encountered consisted of loose-to-medium compact brown-to-gray fine sands, with varying amounts of medium-to-fine sand, silt, and organic matter. This stratum is deltaic in nature resulting from the flow of Cattaraugus Creek into Lake Erie. The thickness of this deposit may change from season to season, as a function of continuing sedimentation and erosion processes. Present-day spring flooding has also contributed to the deposition of these soils at the higher easterly portion of the site.

SOILS CHARACTERISTICS AND FOUNDATION CONDITIONS

C11. The determination of soil characteristics and subsequent description of the same was developed from a field investigation supervised by Haley & Aldrich, Inc., of Cambridge, Massachusetts, during July and August, 1975. Reference 3 presents the complete results of the field exploration and subsequent lab tests. The location and designation of all borings are shown on Plate 1 of the Phase II General Design Memorandum. Soils profiles are also summarized for the breakwaters and channel in Plate C1. The logs of explorations are presented on Plates C2 through C5.

SUBSURFACE CONDITIONS

Breakwaters

C12. Soil conditions disclosed at the north and south breakwaters are described in the logs for Borings D-75-1, -2, -11, -12, -17, -18, -19 and -25 and DU-75-3, -15 and -16. Table C1 presents a general description of subsurface soils conditions encountered at the breakwater site.

C13. The foundation soils have adequate bearing capacity to support the anticipated loads for both the cellular steel sheet-pile and the rubblemound breakwater alternatives. Stability calculations are presented in Appendix D, Detailed Design.

[3] "Subsurface Investigations and Geotechnical Engineering Studies for Cattaraugus Creek Harbor Improvements, Hanover, New York," Sept., 1975, Haley & Aldrich, Inc., Cambridge, Mass.

TABLE C1

BREAKWATER SITE

SUBSURFACE SOILS

Soil Layer Thickness*	Description
2 to 8 ft.	Loose-to-medium compact, brown-to-gray, fine SAND, with varying amounts of medium sand, silt and occasional small amounts of organic matter - Alluvial Deposit
2 to 11 ft.	Medium-compact to compact, gray, gravelly coarse-to-fine SAND or sandy coarse-to-fine GRAVEL - Glacial Outwash
4 to 20 ft.	Medium-compact to compact, well-bonded, gray, gravelly coarse-to-fine SAND or sandy coarse-to-fine GRAVEL, with varying amounts of silt and cobbles - Glacial Till (Upper)
15 to greater than 40 ft.	Very stiff, gray SILT and very compact, gray, silty fine SAND or fine sandy SILT - Glacio-fluvial Deposit
Up to 39 ft.	Medium-stiff to stiff, gray, varved, silty CLAY and clayey SILT, with trace amounts of fine sand in lenses - Glacial Lake Deposit (top 8 ft. hard and desiccated in Borings D-72-2 and D-75-18)

*Sequence of soils beginning at ground level.

C14. Foundation loadings associated with placement of either breakwater alternative to a design crest height of +12 to +14 feet (LWD) are anticipated to induce some settlement of the underlying soils. Minor compression of the alluvial and outwash sand and gravel deposits will occur during construction as filling occurs. Long-term consolidation settlement of the underlying silts and clays can be expected to occur over a period of several years. The greatest consolidation settlement is anticipated to develop near the outer end of the south breakwater where the consolidation settlement is estimated to range from 2 to 3 inches.

Sand Berm

C15. Machine-excavated test pits made at the sand berm location disclosed glacial outwash soils beginning at ground surface. These soils consist of very-loose to loose brown-tan, coarse-to-fine sand to sandy coarse-to-fine gravel, and medium-to-fine sand. Water was encountered during excavation of test pits TP1 and TP2 at El. 578.1 IGLD and 579.8 IGLD, respectively.

C16. The sand berm is proposed to be constructed approximately parallel to the shoreline with a crest height of +11 feet (LWD). The berm will connect the north breakwater to high ground. The alignment of the berm is shown in Plate 1. Riprap is proposed to be placed on the crest and side slopes of the berm. The purpose of the berm is to prevent waves or high river stages from opening a second channel to the north of the north breakwater. No foundation concerns are evident relative to the proposed improvement.

Fills

C17. The generalized sequence of soils disclosed at the fill sites are presented in Table C2. Six feet of weathered shale was encountered at Boring D-75-29 and 10 feet of shale was cored at Boring D-75-14. Water levels measured upon completion of Borings D-75-14 and D-75-29 were at El. 572.4 and El. 571.2, respectively. Water was not encountered in test pits TP7 and TP8 which were terminated at El. 573.2 and El. 571.4, respectively. No foundation concerns are evident relative to the proposed improvements.

TABLE C2

FILL SITES

SUBSURFACE SOILS

Soil Layer Thickness*	Fill No. 1 Description
¼ to ½ ft.	Topsoil
8 to 13.5 ft.	Very-loose to loose, dark brown or gray silty fine SAND or fine sandy SILT, with traces of organics - Alluvial Deposit
13.5 to 22.5 ft.	Loose to compact, brown and gray coarse-to-fine SAND, with traces of silt and gravel - Glacial Outwash
Up to 15.5 ft.	Compact to very-compact, gray, silty fine SAND and fine sandy SILT - Glacio-fluvial Deposit

Water levels in completed Boreholes D-75-13 and D-75-28 were at El. 573.3 and 573.9, respectively.

Soil Layer Thickness*	Fill No. 2 Description
12 to 13 ft.	Loose to medium-compact, brown, fine SAND to fine sandy SILT - Alluvial Deposit
5 to 7.5 ft.	Medium-compact, gray, coarse-to-fine SAND, little silt - Glacial Outwash
17 ft. (D-75-14)	Medium-compact to very compact, gray, silty coarse-to-fine SAND to sandy SILT - Glacial Till (Lower)
4 ft. (D-75-29)	Medium-compact, gray, SILT - Glacio-fluvial Deposit

*Sequence of soils beginning at ground surface.

DREDGING AND SPOILS DISPOSAL

SOIL CONDITIONS

C18. Soil conditions encountered within Cattaraugus Creek are described in the logs for D-75-4 through D-75-9 and D-75-21, D-75-22, and D-75-23. With the exception of Boring D-75-4, all borings were made to a maximum depth of 10 feet and encountered and were terminated within glacial outwash soils. Boring D-75-4 was advanced to a depth of 31.5 feet and disclosed glacial till and glacio-fluvial soils in addition to the near-surface outwash sands and gravels.

C19. Results of the test borings and a sieve analysis indicate dredged soils from the creek will generally consist of sandy gravels and gravelly sands having less than about 10 percent by weight finer than a No. 200 sieve. The borings within the creek disclosed isolated pockets of fine sand and cobbles. Such materials should be expected to be encountered during dredging.

DREDGING

C20. The material to be dredged from Lake Erie contains some silt and clay-sized particles. These alluvial deposits will be re-suspended during dredging operations, causing temporary turbidity. Bedrock was not encountered during explorations in the lake and creek channel.

REGULATORY CRITERIA, SPOILS

C21. Environmental Protection Agency criteria (1971) for determining the acceptability of dredged spoils for use as fill in or adjacent to water systems are presented in Table C3. The table presents the maximum allowable percentage by weight of various chemical constituents.

TABLE C3

SPOILS - POLLUTION CRITERIA

Chemical Constituents	Max. Allowable Concentration (% Dry Weight)
Volatile solids	6.0
Chemical oxygen demand (COD)	5.0
Total Kjeldahl nitrogen	0.10
Oil-grease	0.15
Mercury	0.0001
Lead	0.005
Zinc	0.005

C22. A sampling and analysis program was conducted in 1975 by the United States Environmental Protection Agency to determine the quality of spoil material proposed to be dredged from Cattaraugus Creek. Soils samples were taken at five stations within the bounds of the proposed dredged channel. The results of the sampling program are given in Table C4. The location of the sample corresponds to the channel station. The U.S.E.P.A. station designation is also given in parenthesis. The results indicate that the soils do not meet criteria previously used for bulk sediment analysis for oil and grease concentrations. However, field observations made during the sampling program indicated that gravel was the dominant material present, followed by sand. No oil appeared to be released from the sediments during handling. The concentration of mercury exceeded criteria in one sample. The E.P.A. has concluded that it would not be necessary to contain the dredged spoil contingent upon results of further analysis of the radioactivity of the sediments introduced into the creek by a radioactive waste disposal facility, Nuclear Fuel Services, Inc., West Valley, New York.

TABLE C4. SUMMARY OF CHEMICAL ANALYSIS OF SOILS SAMPLES

	Percent Dry Weight				
Sample Location (Sta.)	15+00	22+00	28+00	36+00	50+00
E.P.A. Station No.	(1258)	(1259)	(1260)	(1261)	(1262)
Volatile Solids	0.4	1.0	1.1	1.2	2.2
C.O.D.	0.7	0.2	0.5	0.9	1.1
Total Kjedahl Nitrogen	0.0044	0.0056	0.0142	0.0053	0.0088
Oil - Grease	0.414	0.225	0.371	0.481	0.661
Mercury	0.00141	<0.00002	<0.00002	<0.00002	<0.00002
Lead	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
Zinc	0.0040	0.0053	0.0034	0.0038	0.0043

DESIGN AND CONSTRUCTION CONSIDERATIONS

BREAKWATERS

C23. Recommended design parameters to be applied to the in-situ soils are presented in Table C5. These soils properties were determined through analysis of samples taken from the 1975 subsurface exploration program.

TABLE C5. IN-SITU SOILS CONSTANTS

Soil Type	Alluvial Fine Sands	Outwash Sand & Gravel, Glacial Till
Total Unit Weight, pcf	125	135
Buoyant Unit Weight, pcf	63	73
Friction Angle, Ø	30^{o}	36^{o}
Lateral Earth Pressure Coef.	0.50	0.41

C24. Alluvial fine sand which covers the lake bottom in a layer ranging from 2 to 8 feet in the vicinity of the breakwater is not adequate to support the core material. A 1-foot minimum thickness layer of sand and gravel should be placed over the alluvial sand to reduce initial settlement and scour. Sand and gravel obtained from the dredged material from the Cattaraugus Creek channel is suitable for this purpose. This bedding layer is not a filter layer as is used in design of a channel lining where sudden drops in water surface induce hydrostatic pressures from the soil toward the channel.

CONSTRUCTION MATERIALS

GENERAL

C25. Materials required for construction of the breakwater, fills, riprap protection, and berm are presented in this section. The primary construction materials are quarry stone, earth fill, and concrete. The list of construction materials is based upon the project configuration of the Detailed Design Appendix. The plan includes two breakwaters, a berm, a riprap protection, and two compacted fill areas.

QUALITY OF QUARRY STONE

C26. Quarry stone used for the breakwater, riprap, and berm should be sound, durable, and hard. The stone should be free from laminations, weak cleavages, and undesirable weathering. The stone should be of character that it will not disintegrate in the action of air, water, or in handling and placing. All stone shall be clean and free from earth, clay, refuse, and adherent coating. Individual quarry stones shall be angular with the greatest dimension no greater than three times the least dimension. The quarry stone should be of the type that has had a suitable performance record in the vicinity of the project location. If the quarry stone or aggregate is from a source without a viable record, the stone may be subject to tests, including a petrographic analysis, abrasion (freeze-thaw and wet-dry), absorption, and reaction to alkali in the case of aggregate.

C27. The surface saturated dry unit weight shall not be less than 150 pounds per cubic foot for armor stone and 140 pounds per cubic foot for underlayer and core material in accordance with CRC-C-107-69 or ASTM C 127. The sizes, gradations, and quantities of stone given below were based on the assumption that the unit weight of armor stone is 165 pounds per cubic foot. The maximum abrasion of stone is 55 percent in accordance with CRD-D-117-67 or ASTM C 131.

ARMOR STONE FOR RUBBLEMOUND BREAKWATERS

C28. Armor stone for rubblemound breakwaters shall comprise four sizes of randomly graded, angular stone designated A6, A4, A3, and A1. These size designations refer to the weight in tons of the size of which 75 percent is greater than by weight. Size, gradations, and quantities of these stones are listed in Table C6 for the north and south breakwaters:

TABLE C6

BREAKWATER ARMOR STONE GRADATIONS

	Gradation	Quantity[1]
A6 Quarry Stone	W_{max} = 12 ton	
	W_{75} = 6 ton	
	W_{min} = 4 ton	30,000 tons
A4 Quarry Stone	W_{max} = 8 ton	
	W_{75} = 4 ton	
	W_{min} = 2.5 ton	8,400 tons
A3 Quarry Stone	W_{max} = 6 ton	
	W_{75} = 3 ton	
	W_{min} = 2 ton	8,300 tons
A1 Quarry Stone	W_{max} = 2 ton	
	W_{75} = 1 ton	
	W_{min} = .75 ton	2,100 tons

[1]Conversion from cubic yards to tons by assuming $\gamma = 165$ pcf, 37% voids, and 10% overrun.

UNDERLAYER FOR BREAKWATERS

C29. The underlayer materials for the rubblemound breakwaters shall comprise quarry stone with gradations listed in Table C7.

TABLE C7

BREAKWATER UNDERLAYER MATERIAL

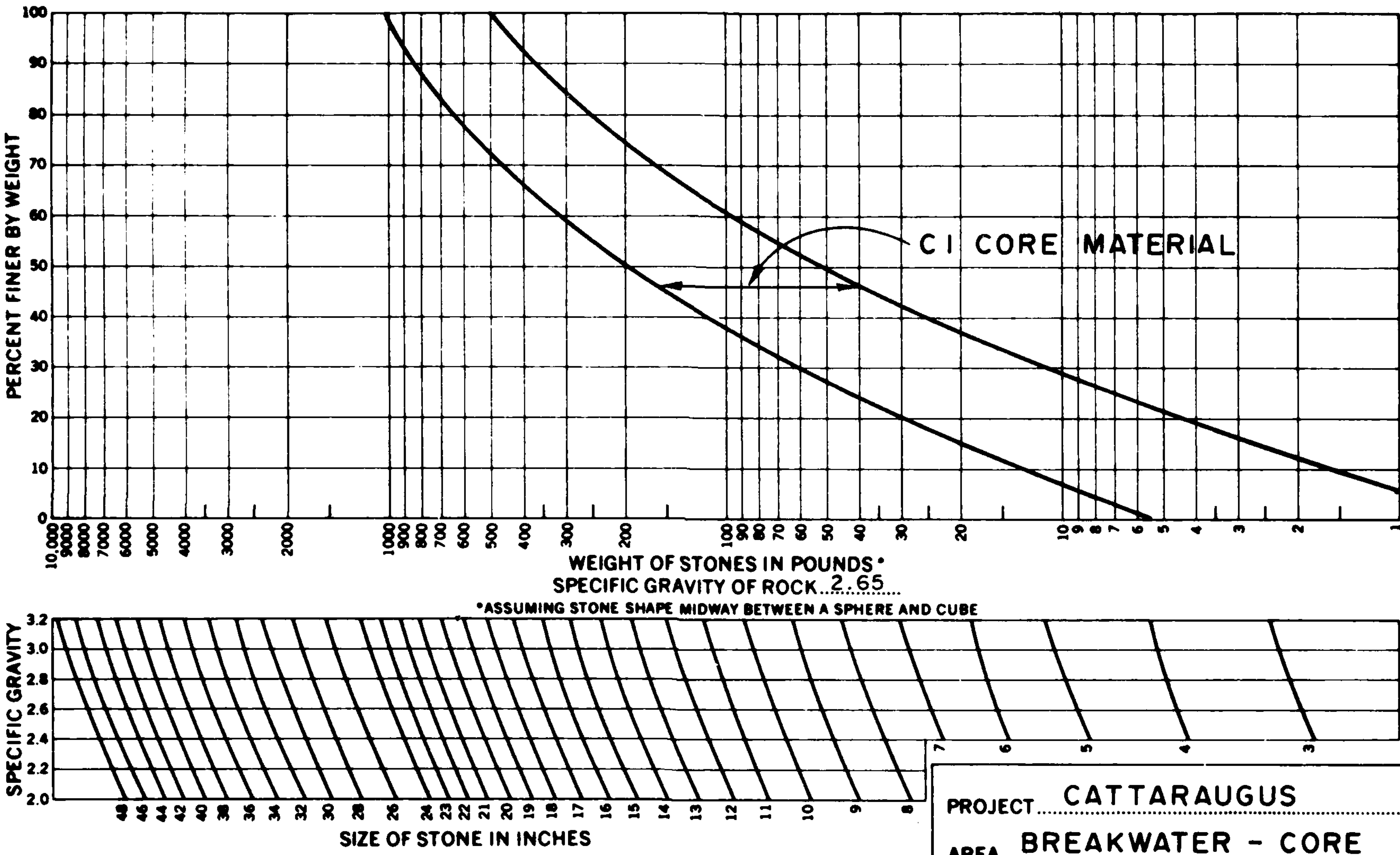
Underlayer	Gradation	Quantity
B.6 Quarry Stone	W_{max} = 2,400 lb. W_{50} = 1,200 lb. W_{min} = 600 lb.	5,300 tons
B.4 Quarry Stone	W_{max} = 1,600 lb. W_{50} = 800 lb. W_{min} = 400 lb.	1,100 tons
B.3 Quarry Stone	W_{max} = 1,200 lb. W_{50} = 600 lb. W_{min} = 300 lb.	1,500 tons

CORE MATERIAL

C30. The breakwater core material, C1, shall comprise a randomly graded core material stone. The core is to provide the underlayer for the A1 armor stone. The core, which has wide gradation limits, is placed in a 3-foot layer to provide an impervious barrier to littoral drift and transition to the bedding layer. The maximum size of core material is 1000-pound and the minimum size is one-inch. Fifty percent of the material will be greater than 50 pounds. Gradations and quantities are listed in Table C8 and the gradation curve is given in Figure C1.

TABLE C8. CORE STONE, C1

Percent Finer by Weight	Size	Quantity
100	1000 to 500 lb.	
50	200 to 50 lb.	
0	1 to 4 inch	32,000 tons



PROJECT CATTARAUGUS

AREA BREAKWATER - CORE

DATE 12-12-75

RIPRAP GRADATION CURVES

ENG FORM 4055
APR 67

FIGURE C1

BEDDING MATERIAL

C31. A bedding material is required for the breakwaters where the in-situ soils comprise a loose sandy silt. Material dredged from the sand spit and creek is adequate for this purpose. Table C9 lists the gradations of the in-situ creek dredge material. Figure C8 gives the gradation of the sand spit material from Boring TP-75-1. Figures C2 through C6 give the gradations of the creek material.

TABLE C9. CREEK DREDGE MATERIAL, D1

Sieve Size	Percent Finer by Weight	Quantity
2 in.	100	
½ in.	60 - 100	
#4	35 - 70	
#10	15 - 55	
#100	0 - 10	10,000 CY

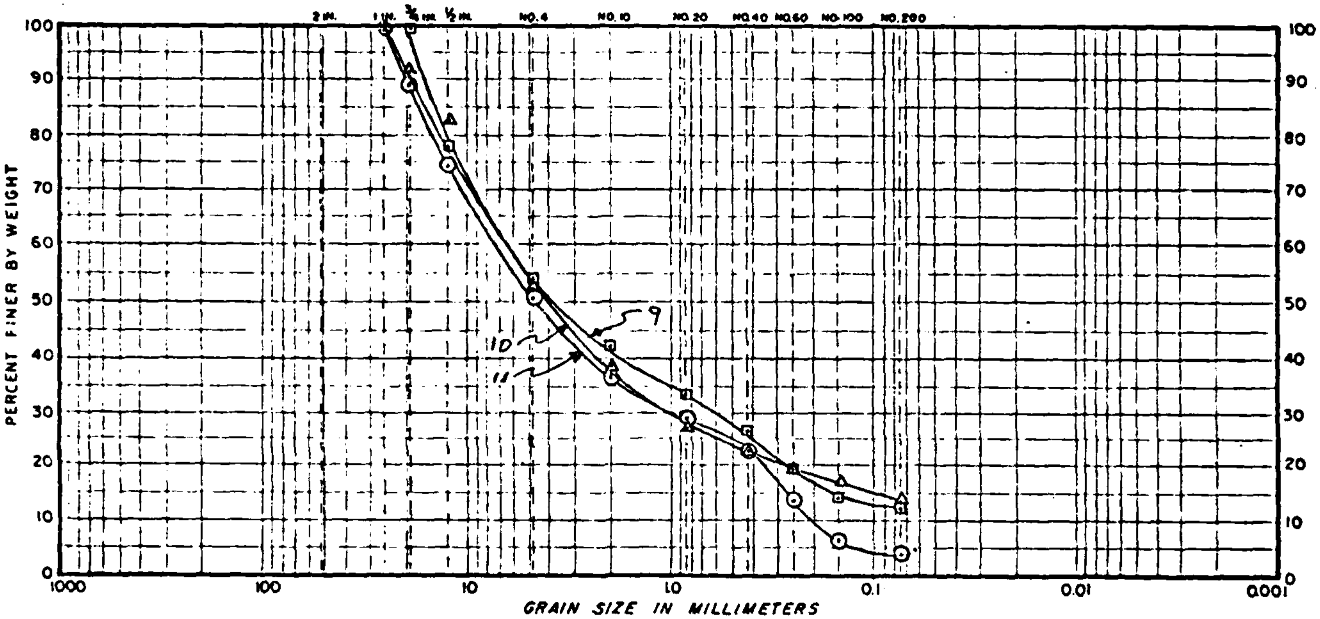
FILLS

C32. The fills should be constructed of homogeneous semi-impervious earth mounds having side slopes not steeper than 3 horizontal to 1 vertical and with minimum crest widths of 5 feet. Erosion of the fills should be minimized by the placement of topsoil and seeding on the crests and side slopes. The topsoil surface should not be placed above the design crest heights. The semi-impervious fill should consist of silty soils which are free of organic matter, loam, trash, snow, ice, frozen soil and other objectionable materials, and well-graded within the limits given in Table C10 and shown in Figure C7.

TABLE C10. FILL MATERIAL GRADATION

Sieve Size	Percent Finer by Weight	Quantity
6 in.	100	
#4	60 - 100	830 CY
#40	40 - 90	
#200	25 - 60	

GRAIN SIZE DISTRIBUTION



UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

Test No.	Boring No.	Jar No.	Depth	Description
9	D-75-4	2	2'-4'	gray sandy fine GRAVEL, trace silt
10	D-75-4	3	4'-6'	brown sandy fine GRAVEL, little silt
11	D-75-4	6	15'-17'	gray to brown sandy fine GRAVEL, little silt

PROJECT Cattaraugus Creek Harbor Improvements - Hanover, New York

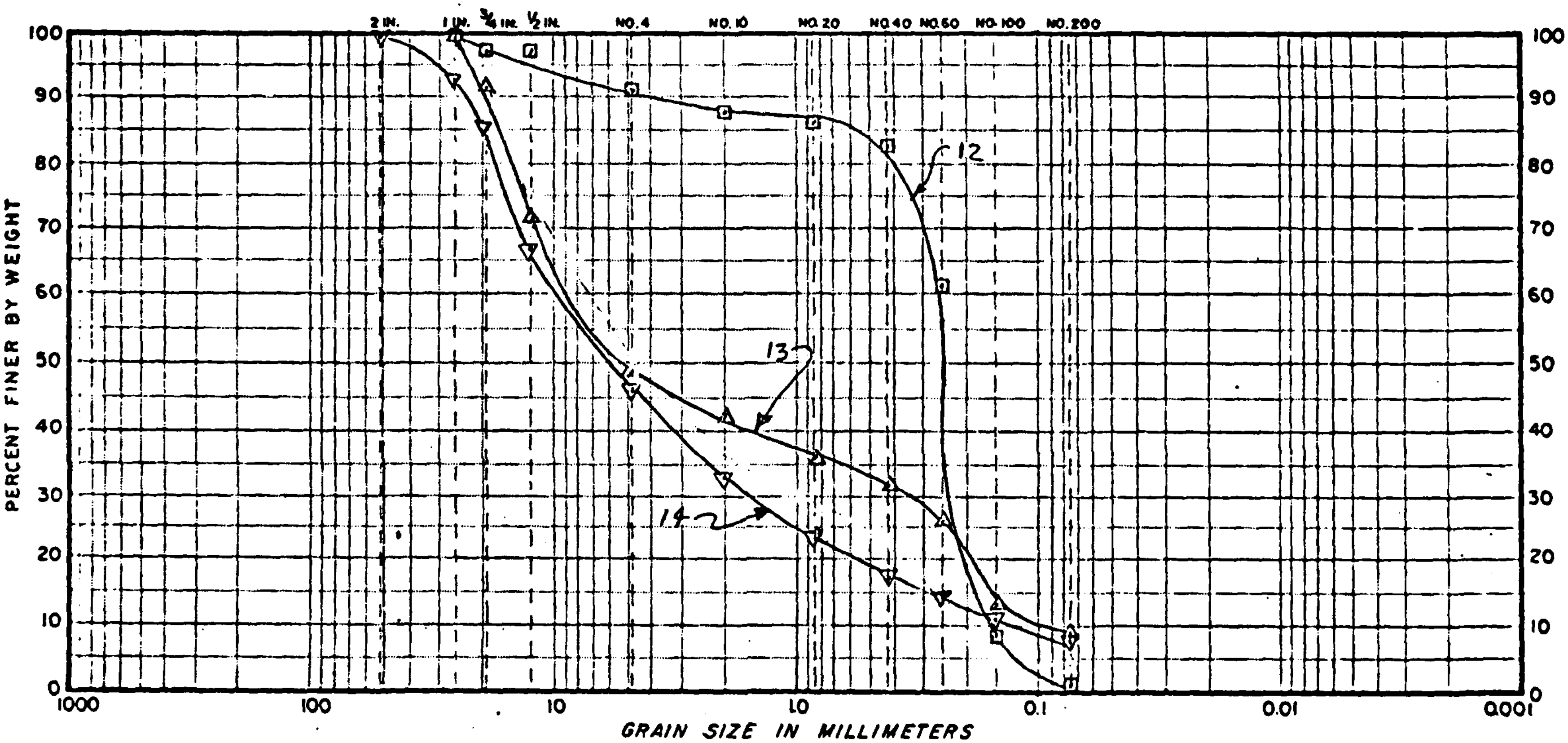
FILE NO. 3655 DATE August 1975

HALEY & ALDRICH, INC.

FIGURE

HALEY & ALDRICH, INC.

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S ARMY

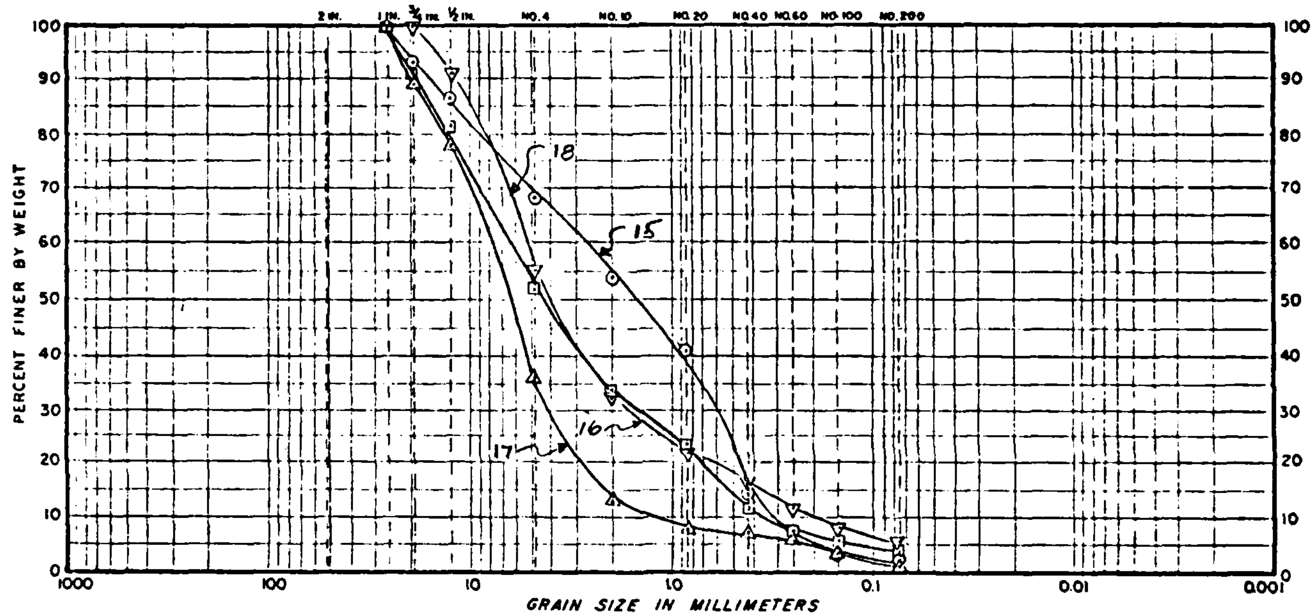
Test No.	Boring No.	Jar No.	Depth	Description
12	D-75-5	1	0'-2'	brown medium to fine SAND, trace gravel
13	D-75-5	2	2'-4'	gray sandy fine GRAVEL, trace silt
14	D-75-5	3	4'-6'	gray sandy fine GRAVEL, trace silt

PROJECT Cattaraugus Creek Harbor Improvements - Hanover, New York

FILE NO. 3655 DATE September 1975

FIGURE C6

GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S ARMY

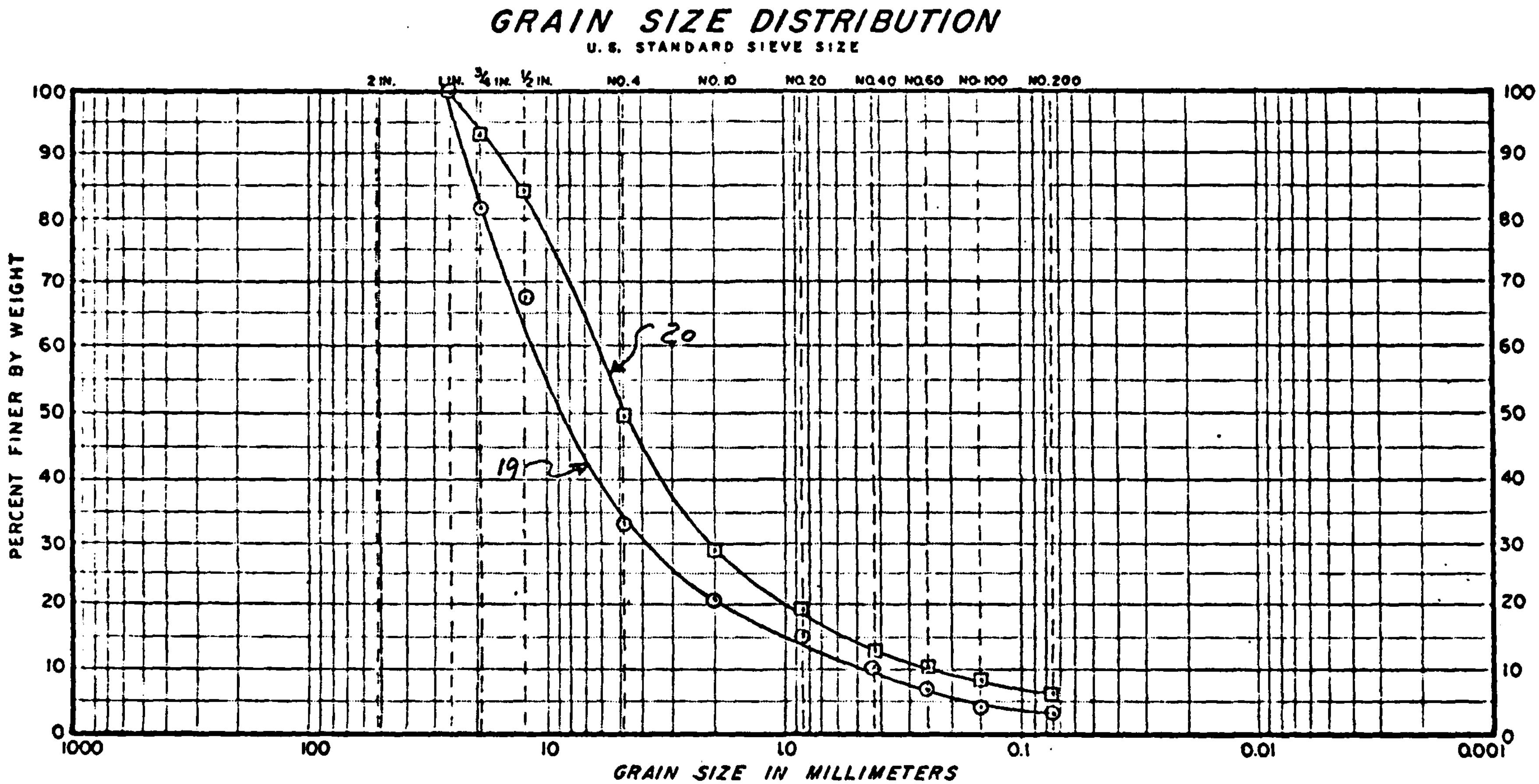
Test No.	Boring No.	Jar No.	Depth	Description
15	D-75-7	2	2'-4'	gray fine gravelly coarse to medium SAND, trace fine sand
16	D-75-7	3	4'-6'	gray sandy GRAVEL, trace silt
17	D-75-8	1	0'-2'	gray sandy GRAVEL, trace silt
18	D-75-8	2	2'-4'	gray fine gravelly coarse to fine SAND, trace silt

PROJECT Cattaraugus Creek Harbor Improvements - Hanover, New York

FILE-NO. 3655 DATE August 1975

HALEY & ALDRICH INC.

FIGURE C4



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S ARMY

Test No.	Boring No.	Jar No.	Depth	Description
19	D-75-9	1	0'-2'	gray sandy fine GRAVEL, trace silt
20	D-75-9	3	4'-6'	gray sandy fine GRAVEL, trace silt

PROJECT Cattaraugus Creek Harbor Improvements - Hanover, New York

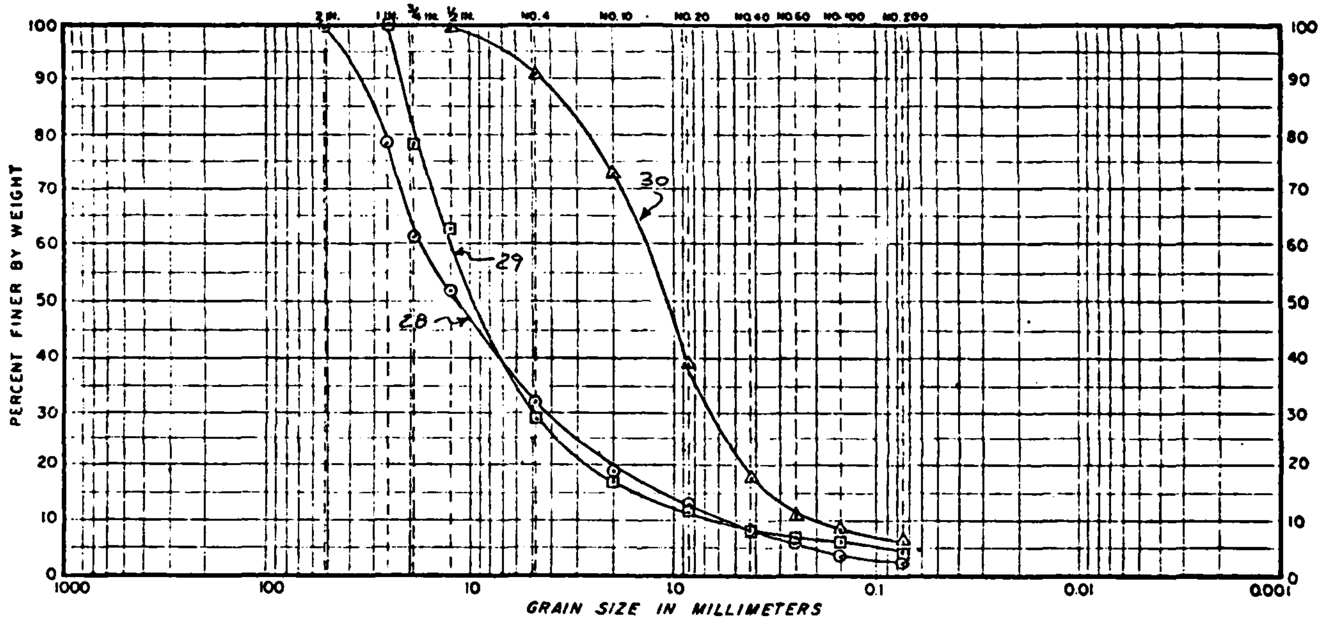
FILE NO. 3655 DATE September 1975

HALEY & ALDRICH, INC.

FIGURE C5

GRAIN SIZE DISTRIBUTION

U. S. STANDARD SIEVE SIZE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

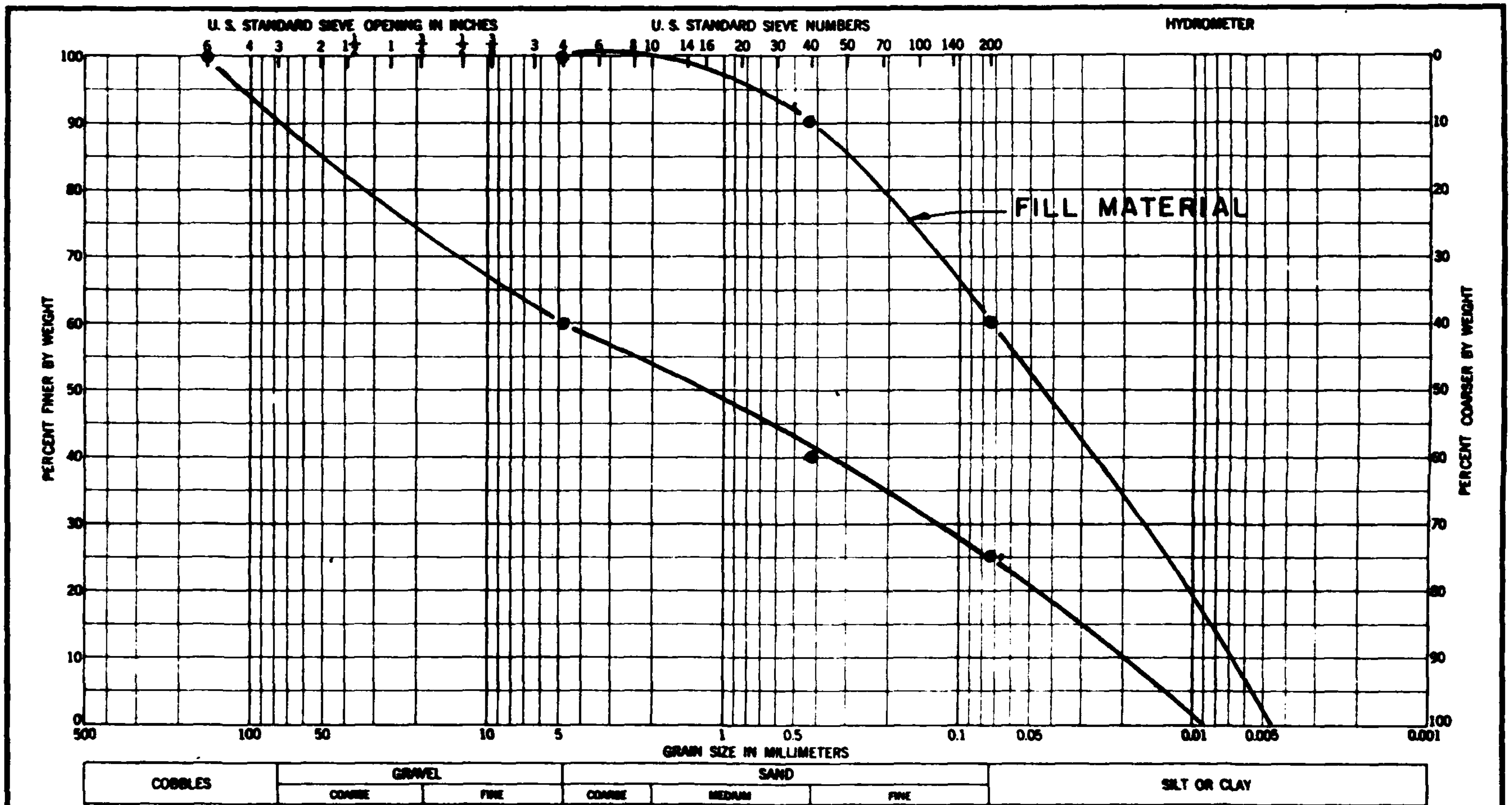
Test No.	Boring No.	Jar No.	Depth	Description
28	D-75-23	1	0'-2'	gray to brown gravelly coarse to fine SAND, travc silt
29	D-75-23	2	2'-4'	gray gravelly coarse to fine SAND, trace silt
30	D-75-23	3	4'-6'	gray coarse to fine SAND, trace fine gravel

PROJECT Cattaraugus Creek Harbor Improvements - Hanover, New York

FILE NO. 3655 DATE September 1975

HALEY & ALDRICH INC

FIGURE C6



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project CATTARAUGUS CREEK

Area FILL

Boring No.

Date 12-12-75

GRADATION CURVES

ENG FORM 1 MAY 63 2087

FIGURE C7

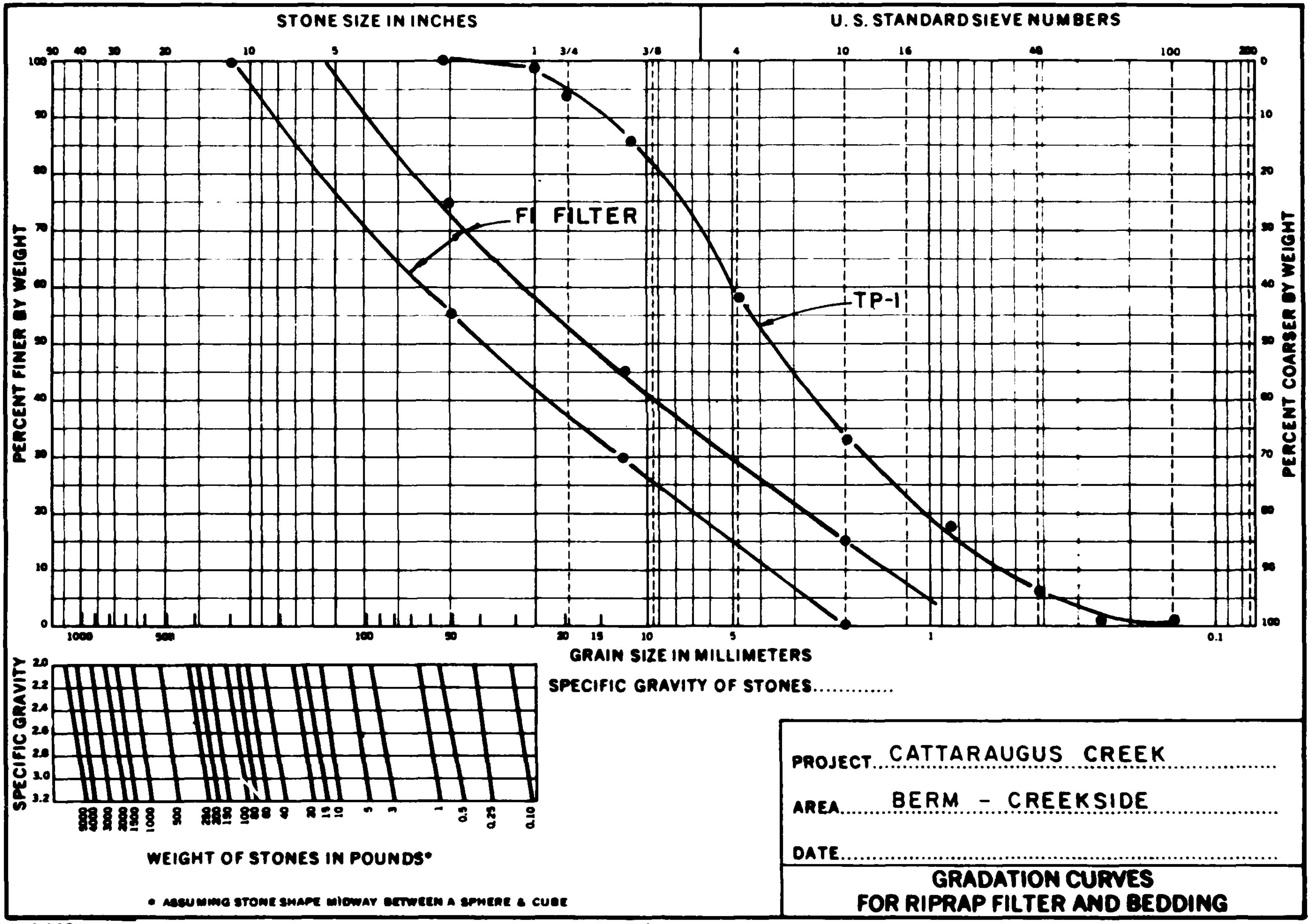
C33. Topsoil and organic matter should be stripped from the proposed fill locations. Logs, driftwood, and stumps that exist within the fill area of the berm should also be removed. The exposed bearing soils should be proof rolled and compacted by self-propelled vibratory compactors. Soft spots disclosed by proof rolling should be excavated to firm soil and backfilled with compacted fill of the type recommended for the fill structures. Fill soils should be placed in loose layer thicknesses not exceeding 9 inches and the soils should be compacted to at least 92 percent of maximum dry density as determined by ASTM Test Designation D 1557, Method D. Sheepsfoot or pneumatic-tired rollers should be used for fill compaction. Fill soils should be placed and compacted laterally outward beyond the design side slopes as necessary to achieve thorough compaction within the final slopes. Following compaction, the side slopes should be trimmed to design grade in a manner that will not disturb the compacted soils.

BERM

C34. The in-situ soils along the berm comprise a coarse sand shown in the gradation curve in Figure C8. An 8-inch minimum thickness filter material, F1, with gradation limits given in Table C11 and shown in Figure C8 is required to transition the in-situ soils to the riprap armor. The riprap armor, B.1, for the creek side comprises a quarry stone with gradations given in Table C12. The riprap armor gradation for the creek side of the berm also serves as the underlayer for the lake-side armor. The lake-side armor gradations and quantities are given in Table C13. Berm armor, filter, and underlayer gradations were designed based on criteria established in EM 1110-2-1401, EM 1110-2-1601, and the Shore Protection Manual.

TABLE C11. BERM FILTER, F1

Sieve Size	Percent Finer by Weight	Quantities
12 in.	100	
2 in.	55 - 75	
½ in.	30 - 45	
#10	0 - 15	4,300 tons



ENG FORM 4056
APR 67

FIGURE C8

TABLE C12. BERM RIPRAP AND UNDERLAYER

	Gradation	Quantity
B.1 Stone	W = 400 lb.	
	W = 200 lb.	
	W = 100 lb.	5,400 tons

TABLE C13. BERM ARMOR

	Gradation	Quantity
A1 Stone	W = 4,000 lb.	
	W = 2,000 lb.	
	W = 1,500 lb.	5,800 tons

CHANNEL RIPRAP

C35. Riprap armor for the channel stabilization on the outer bank of the channel shall comprise a randomly graded, angular quarry stone designated R.5. The size, gradation, and quantities of the riprap are given in Table C14 and the gradation is shown in Figure C9. Riprap requirements were determined based on criteria established in EM 1110-2-1601, Hydraulic Design of Flood Control Channels.

TABLE C14. CHANNEL RIPRAP ARMOR

	Gradation		
	Percent Finer by Weight	Weight (lbs)	Quantity
R.5 Quarry Stone	100	2000 to 4000	
	50	1000 to 1300	
	15	250 to 1000	7,500 tons

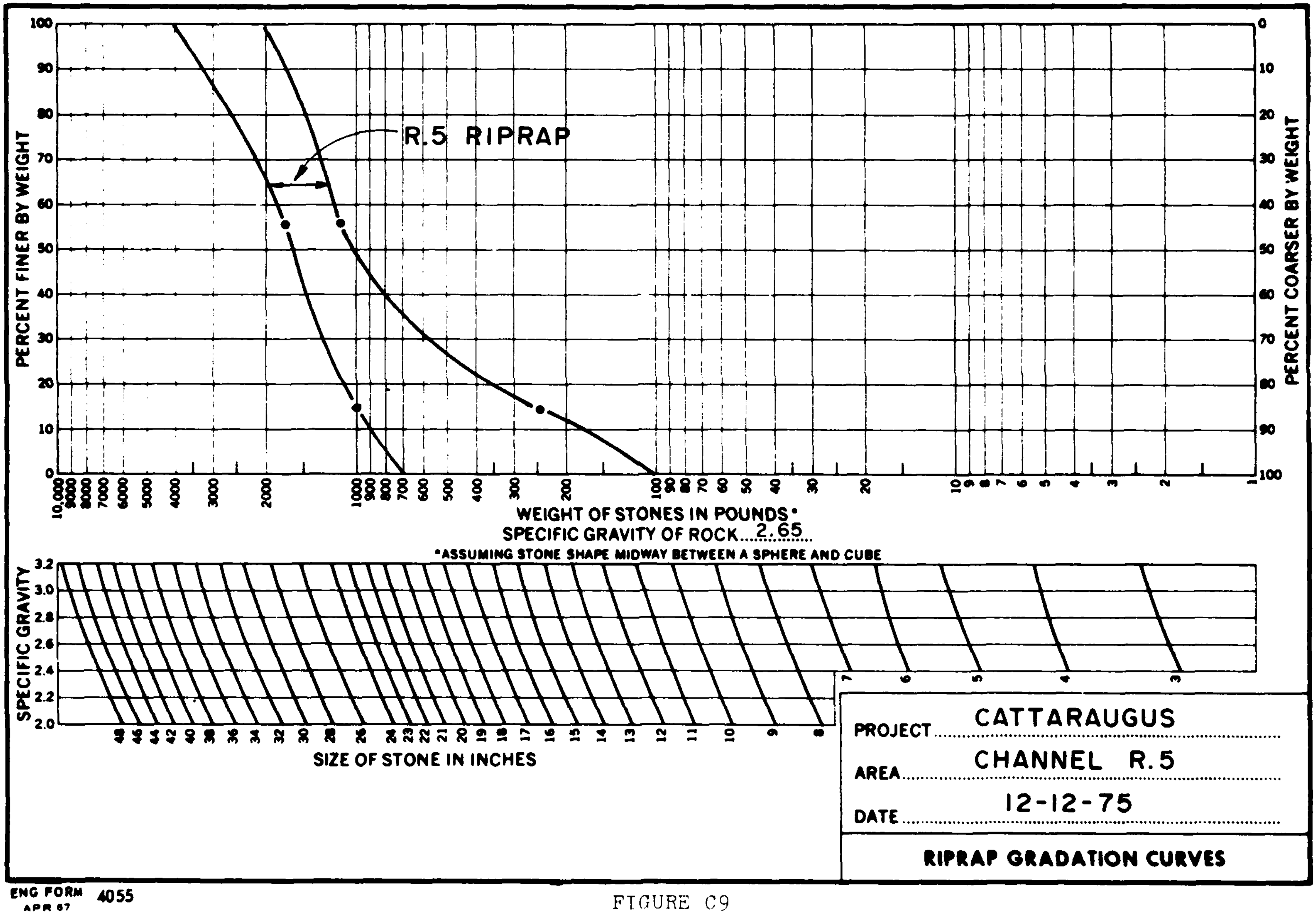

R.5 RIPRAP
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
WEIGHT OF STONES IN POUNDS*
SPECIFIC GRAVITY OF ROCK 2.65
*ASSUMING STONE SHAPE MIDWAY BETWEEN A SPHERE AND CUBE
SPECIFIC GRAVITY
SIZE OF STONE IN INCHES
PROJECT CATTARAUGUS
AREA CHANNEL R.5
DATE 12-12-75
RIPRAP GRADATION CURVES
ENG FORM 4055
APR 67

FIGURE C9

CHANNEL FILTER

C36. The channel riprap requires a filter material, F2, with the gradations shown in Figure C10 and given in Table C15. The filter material shall comprise a randomly graded quarry stone. Filter requirements were determined based on criteria established in EM 1110-2-1901, Soil Mechanics Design Seepage Control.

TABLE C15. CHANNEL FILTER, F2

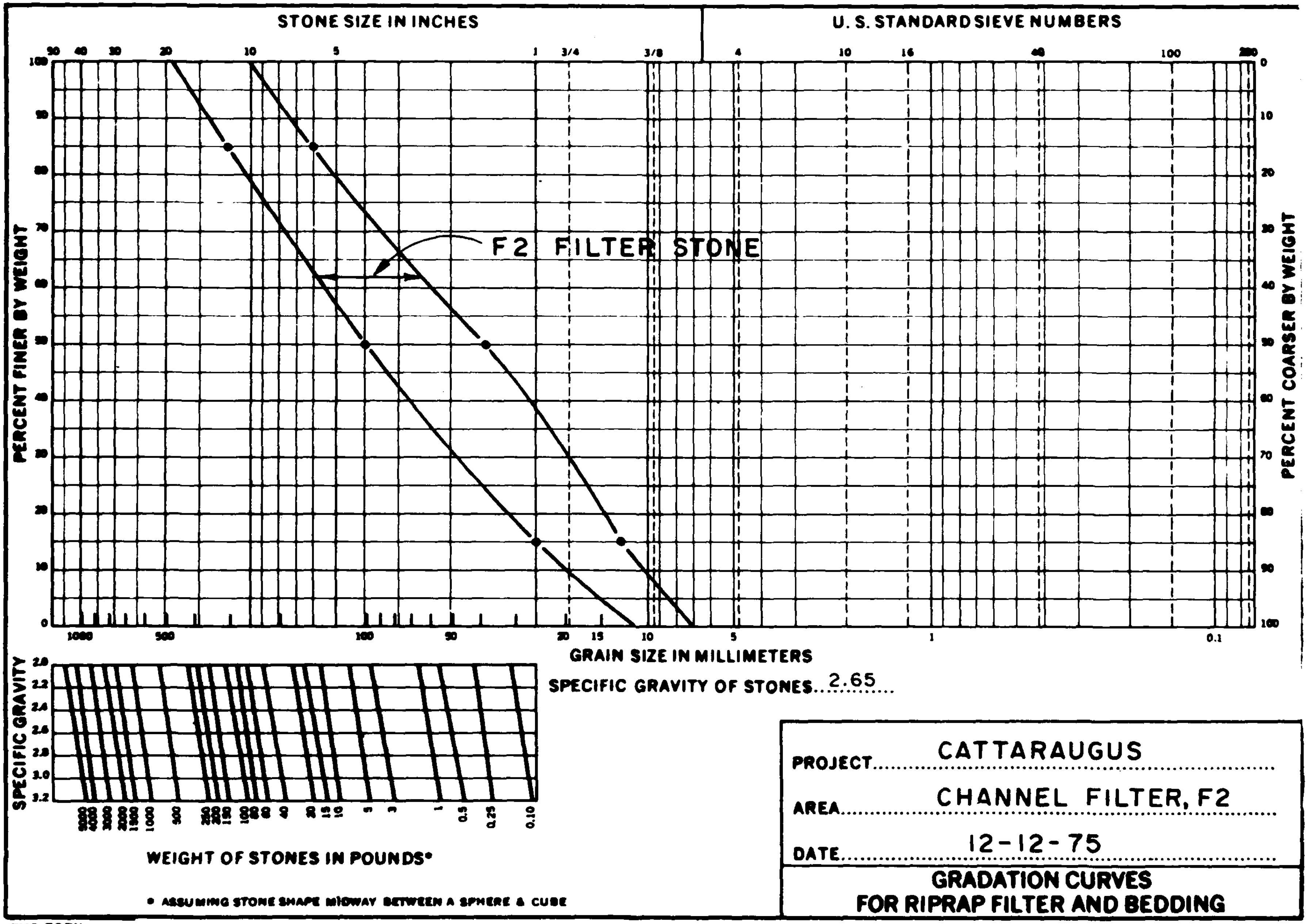
	Percent Smaller Than by Weight	Stone Size (inches)	Quantity
F2 Quarry Stone	100	10-20	
	85	6-12	
	50	1.5- 4	
	15	0.5- 1	2,600 tons

COARSE AGGREGATES FOR CONCRETE

C37. Coarse aggregates shall consist of a gravel, crushed stone, or crushed gravel having the gradation listed in Table C16 and shall fall within the limits shown in Figure C11. This gradation is taken from New York State Specification 703-2, Table 703-4.

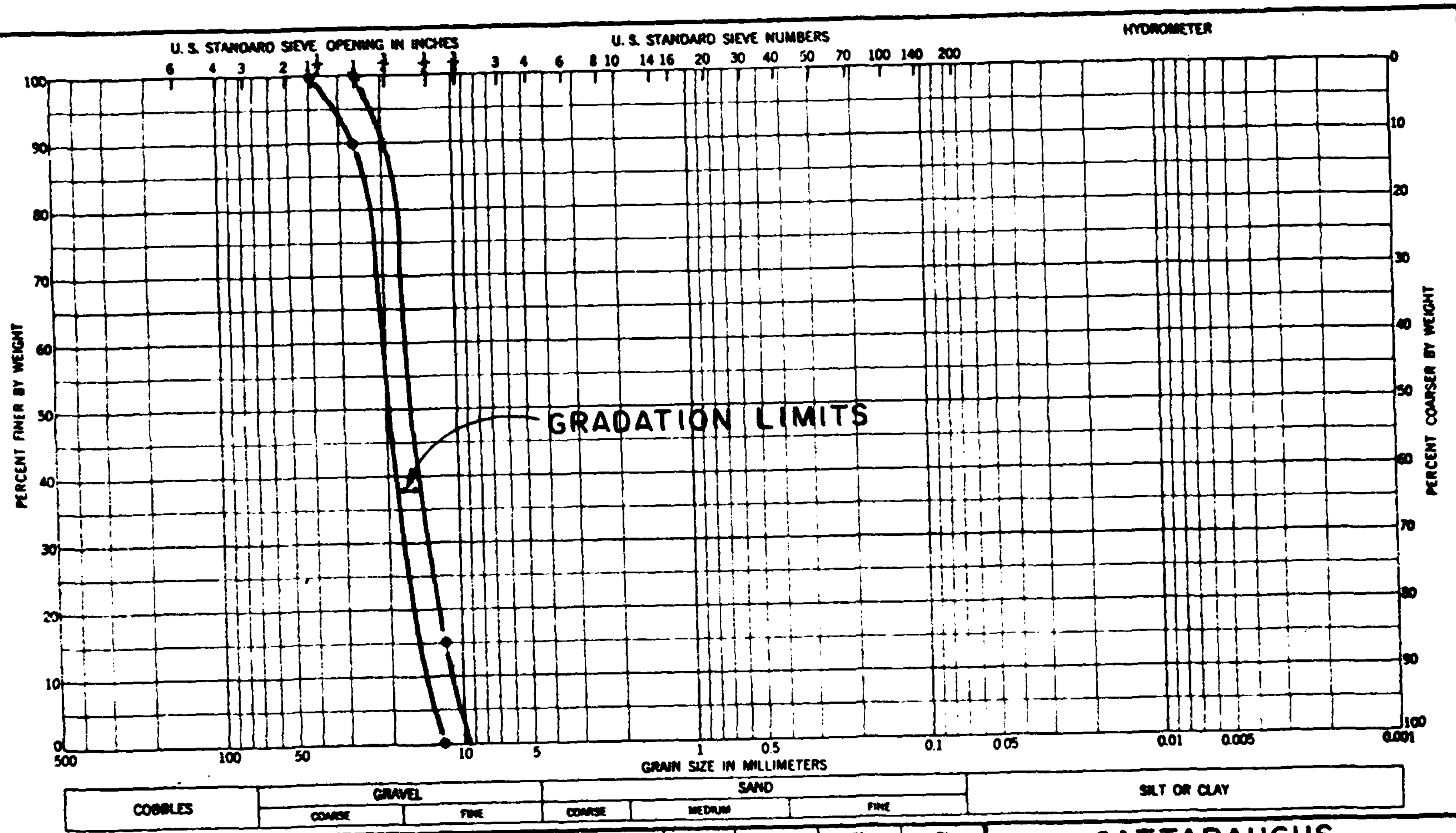
TABLE C16. COARSE AGGREGATE

Sieve Designation U.S. Standard Square Mesh	Percent Finer by Weight
1½"	100
1"	90 - 100
½"	0 - 15



ENG FORM 4056
APR 67

FIGURE C10



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project CATTARAUGUS

Area COARSE AGGREGATE

Boring No. G.D.M. PHASE II

Date 12-12-75

GRADATION CURVES

ENG FORM 1 MAY 63 2087

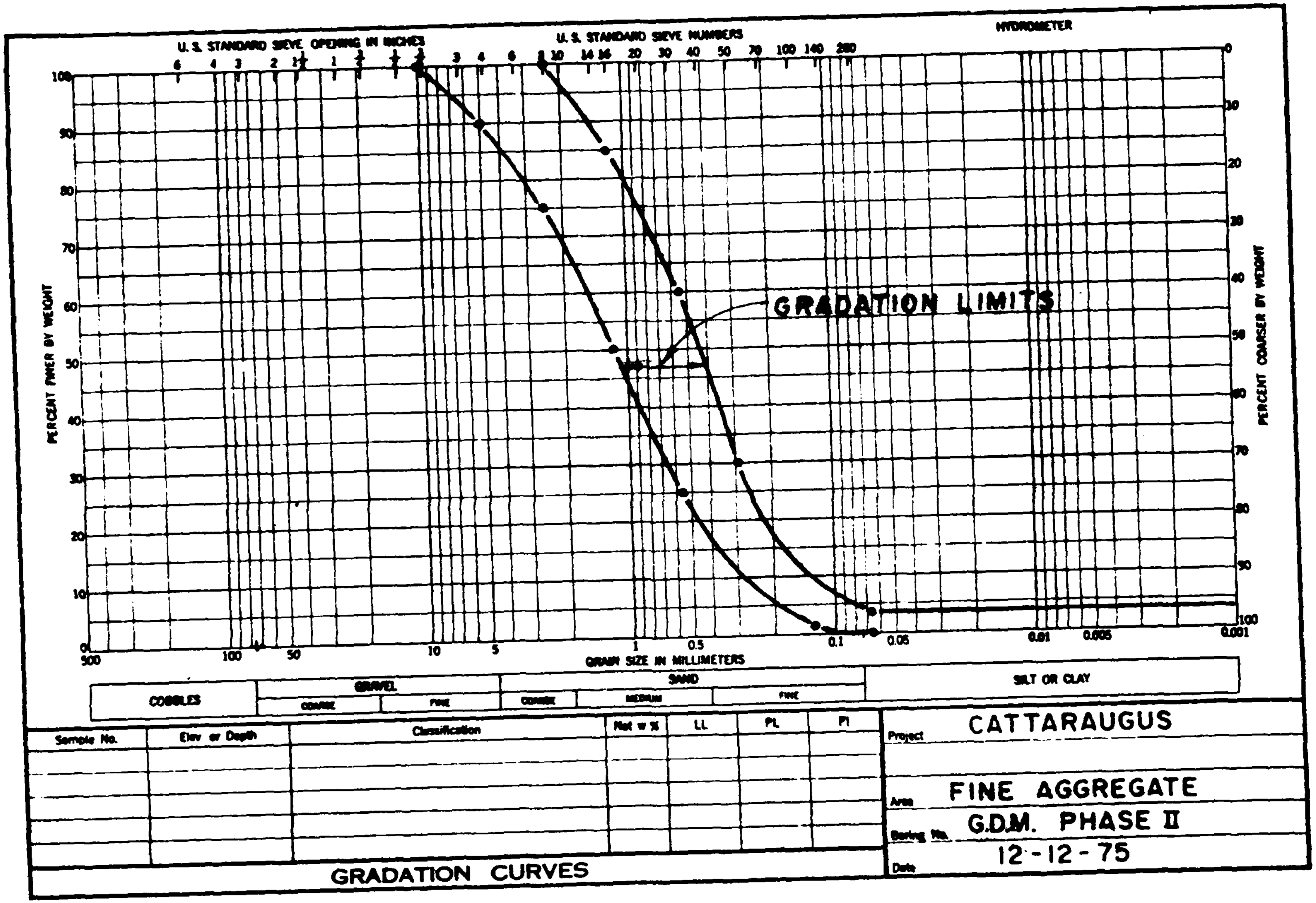
FIGURE C11

FINE AGGREGATES FOR CONCRETE

C38. Fine aggregates shall consist of a gravel, natural sand, manufactured sand, or a combination of natural and manufactured sand having the gradation shown in Table C17 and shall fall within the limits shown on the gradation curve on Figure C12. New York State Specification 703-7 was used in lieu of Corps of Engineers' specifications due to characteristics of materials available near the project site.

TABLE C17. FINE AGGREGATE

Sieve Designation U.S. Standard Square Mesh	Percent Finer by Weight
3/8"	100
#4	90 - 100
#8	75 - 100
#16	50 - 85
#30	25 - 60
#50	10 - 30
#100	1 - 10
#200	0 - 3



ENG FORM 1 MAY 63 2087

FIGURE C12

MATERIALS SURVEY

POSSIBLE SOURCES

C39. The required stone materials to construct the breakwaters, channel riprap, and berm can be produced from the sources indicated on Plates C7 through C16 "Possible Sources". Sources that were investigated and sampled by the Buffalo District and tested by the Ohio River Division Laboratory are summarized on the plates "Laboratory Test Results" and are listed in alphabetical order by states; i.e. New York, Ohio, Michigan and Pennsylvania on Plates C17 through C32. All materials from these sources may not be suitable. The right will be reserved in the specification to reject materials from certain localized areas, zones, strata, channels, or stockpiles when such materials are determined as unsuitable.

C40. It is anticipated that selective quarrying will be required for some materials types. Blasting techniques used for normal production will require adjustments or in some cases complete tailoring to produce cover stone. The specifications shall state that the Contractor require the source to designate lifts, beds, and/or areas of the quarry for the production of armor stone. Seasonal blasting and stockpiling of materials will be required prior to delivery at the project. Also, the specifications will require that shale and other undesirable materials will be excluded by adequate processing. All sources proposed by the Contractor will be subjected to retesting prior to use in the project.

C41. There are a total of 49 possible sources listed that are capable of producing various types of stone material. The number of sources listed for each stone type are as follows:

a. Type (A6) Armor Stone: There are 19 possible sources listed as being able to produce this material. The distance from these sources to the project area range from 43 to 452 radial miles.

b. Type (A4) Armor Stone: There are 29 possible sources listed as being able to produce this material. The distance from these sources to the project area range from 43 to 452 radial miles.

c. <u>Type (A3) Armor Stone</u>: There are 29 possible sources listed as being able to produce this material. The distance from these sources to the project area range from 43 to 452 radial miles.

d. <u>Type (A1) Armor Stone</u>: There are 16 possible sources listed as being able to produce this material. The distance from these sources to the project area range from 37 to 191 radial miles.

e. <u>Type (B.6, B.4, B.3) Underlayer Stones</u>: There are 16 possible sources listed as being able to produce these materials. The distance from these sources to the project area range from 37 to 191 radial miles.

f. <u>Type (C1) Core Stone</u>: There are 17 possible sources listed as being able to produce these materials. The distance from these sources to the project area range from 37 to 191 radial miles.

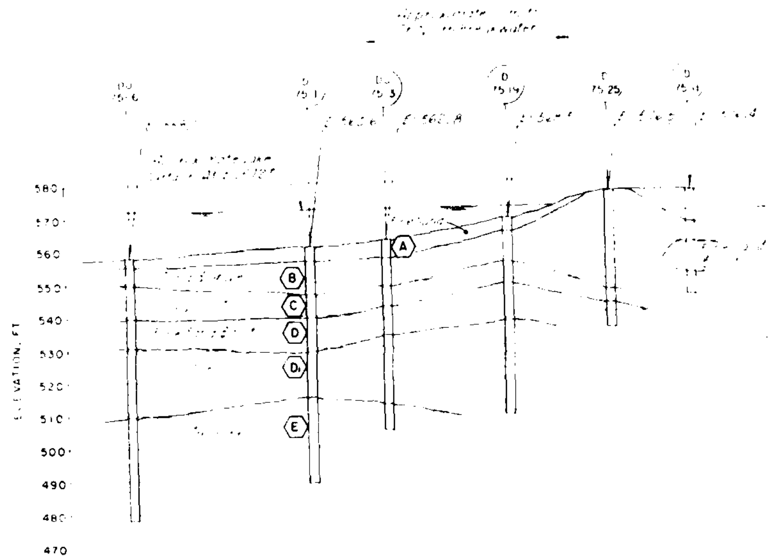
g. <u>Type (F2) Filter Stone</u>: There are 17 possible sources listed as being able to produce these materials. The distances from these sources to the project area range from 37 to 191 radial miles.

h. <u>Type (F1) Filter Stone</u>: There are 15 possible sources listed as being able to produce these materials. The distances from these sources to the project area range from 12 to 191 radial miles.

i. <u>Type (B.1, R.5) Berm Riprap and Channel Armor</u>: There are 17 possible sources listed as being able to produce these materials. The distances from these sources to the project area range from 37 to 191 radial miles.

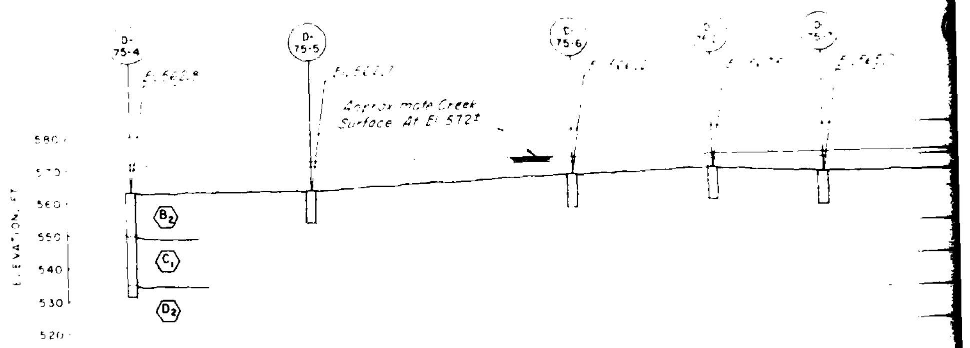
j. <u>Fine Aggregate for Concrete</u>: There are 14 possible sources listed as being able to produce this material. The distance from these sources to the project area range from 12 to 191 radial miles.

k. <u>Coarse Aggregate for Concrete</u>: There are 7 possible sources listed as being able to produce this material. The distance from these sources to the project area range from 37 to 191 radial miles.



PROFILE A-A

NORTH BREAKWATER



PROFILE C-C

CHANNEL

DESCRIPTION OF SOIL STRATA

(A) [illegible] brown to grey fine sands with varying amounts [illegible] organic matter.

(B) [illegible]

(B1) [illegible]

(B2) [illegible]

(C) [illegible]

(C1) [illegible] gravelly [illegible]

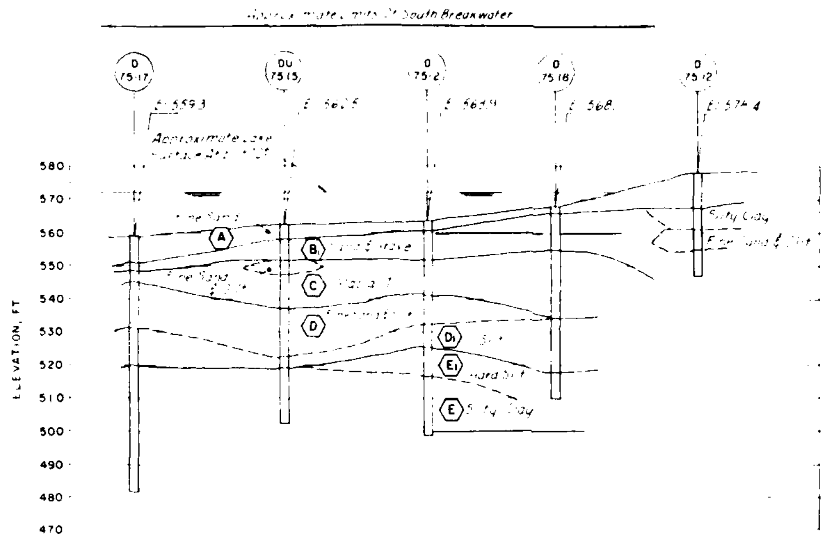
(D) [illegible] fine [illegible]

(D1) [illegible] with [illegible]

(D2) [illegible] fine [illegible]

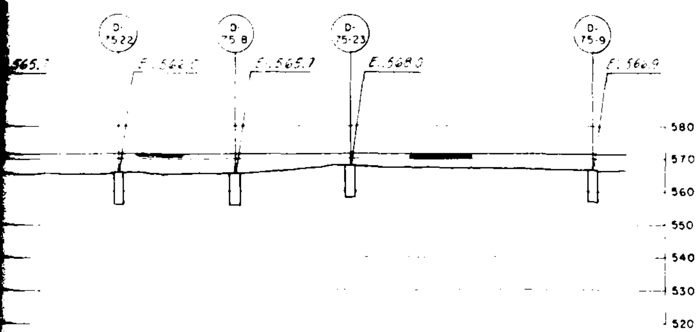
(E) [illegible]

(E1) [illegible] fine sandy silt [illegible]



PROFILE B-B

SOUTH BREAKWATER



NOTES:

1. See Plate 1 for locations of Borings and orientation of Soil Profile.
2. Subsoil stratification lines are interpolations and may not necessarily agree with field conditions.

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
BUFFALO NEW YORK 14207

DRAWN BY J. L. H.
DESIGNED BY
CHECKED BY
SUBMITTED BY
CHIEF, TECHNICAL BRANCH
APPROVAL RECOMMENDED
CHIEF, ENGINEERING DIVISION

CATTARAUGUS CREEK HARBOR, N. Y.

LOGS OF EXPLORATIONS
PROFILES

APPROVED DATE
DISTRICT ENGINEER

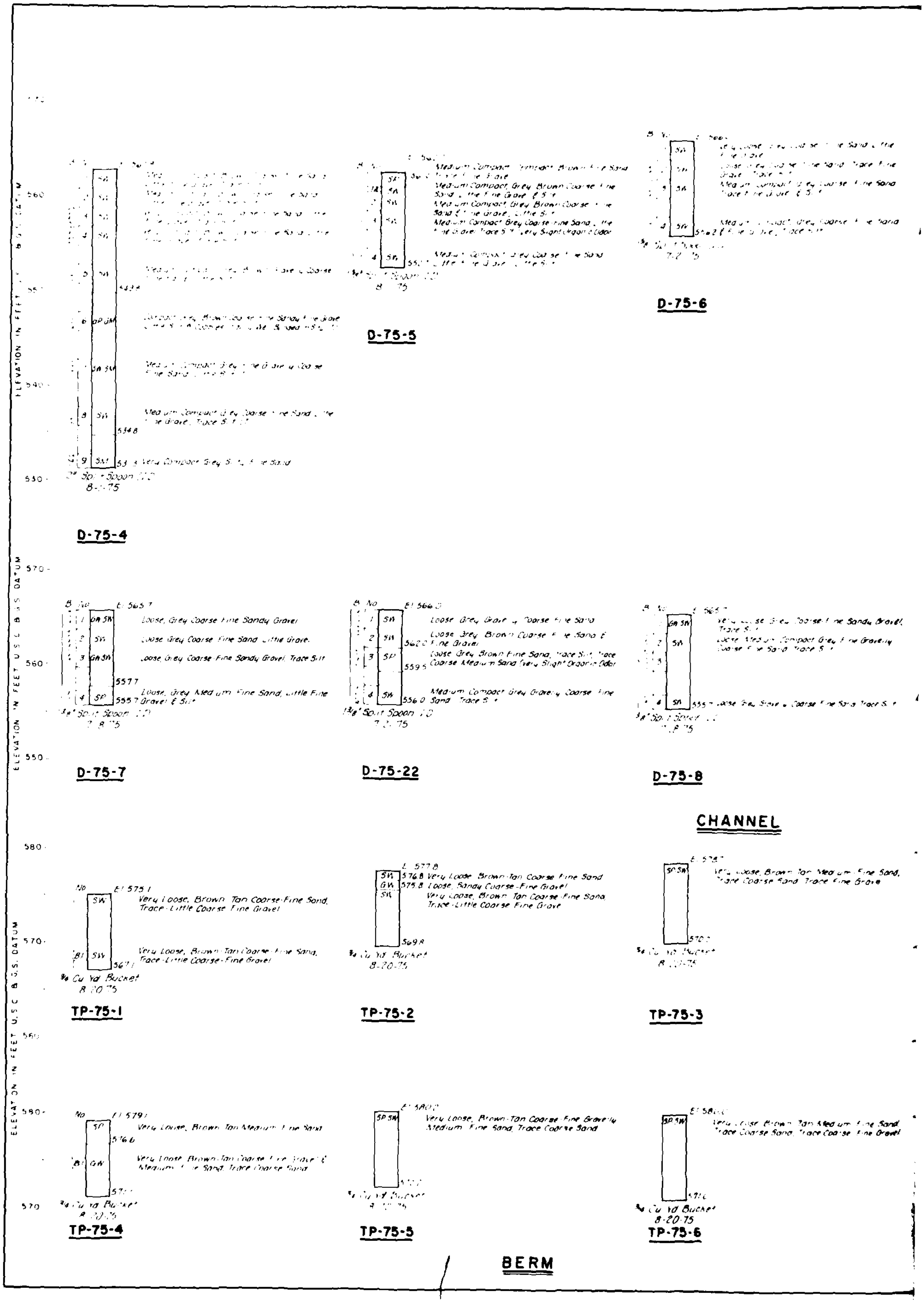
SCALE HOR. 1" = 200'; VERT. 1" = 20'

MOFFATT & NICHOL ENGINEERS
LONG BEACH, CALIFORNIA
ARCHITECT - ENGINEER

TO ACCOMPANY SPECIFICATIONS SERIAL NO. DACW 49 - 7 - B - 00

DRAWING NUMBER
SHEET OF

PLATE C1



D-75-4
D-75-5
D-75-6
D-75-7
D-75-22
D-75-8
CHANNEL
Loose, Grey Coarse-Fine Sandy Gravel
Loose, Grey Coarse-Fine Sand, Little Gravel
Loose, Grey Coarse-Fine Sandy Gravel, Trace Silt
Loose, Grey Medium-Fine Sand, Little Fine Gravel & Silt
Very Loose, Brown-Tan Coarse-Fine Sand, Trace-Little Coarse-Fine Gravel
3/4 Cu Yd Bucket
8-20-75
TP-75-1
TP-75-2
TP-75-3
TP-75-4
TP-75-5
TP-75-6
BERM

LEGEND FOR LOGS OF EXPLORATION

Classification Symbol — SW
Sample Number — 1
Blow Count (Per ½ Foot)
Moisture Content Percent Dry Weight — 29.4
Cohesion Pounds Per Square Foot — 155
Unit Dry Weight Pounds Per Cubic Foot — 117.4
Specific Gravity — 2.72
Plastic Limit — 19.8
Liquid Limit — 36.2
Size Of Sampler — 1⅜" Split Spoon (I.D.)
Date Boring Completed — 8-20-75
Hole Number And Description — D-75-6

D-75-21

- Medium Compact Grey Coarse-Fine Sandy Gravel
- Medium Compact Grey Coarse-Fine Sandy Gravel
- Medium Compact Grey, Red Brown Coarse-Fine Sandy Gravel
- 557.5 Medium Compact Grey, Red Brown Coarse-Fine Sandy Gravel

1⅜" Split Spoon (I.D.)

D-75-23

B No — El 568.0

B No			
1	GW		Medium Compact Grey Sandy Coarse-Fine Gravel, Trace Silt
2	GW	564.0	Medium Compact Grey Sandy Coarse-Fine Gravel, Trace Silt
3	SW	562.0	Medium Compact Grey Coarse-Fine Sand, Trace Fine Gravel & Silt
4	GW-GM	558.0	Medium Compact Grey-Brown Sandy Coarse-Fine Gravel, Little Silt, Tillike (Slightly Bonded In Situ)

1⅜" Split Spoon (I.D.) 7-22-75

D-75-9

B No — El 566.9

B No			
1	GW-SW		Very Loose, Grey Sandy Coarse-Fine Gravel
2			
3	GW-SW		Loose, Grey Sandy Coarse-Fine Gravel
4	SW-GM	556.9	Medium Compact, Grey Gravelly Coarse-Fine Sand, Trace Silt

1⅜" Split Spoon (I.D.) 7-18-75

D-75-24

ELEVATION IN FEET U.S.C. & G.S. DATUM

B No — El 566.3

B No			
1	SM	564.3	Very Loose, Grey Silty Fine Sand, Trace Coarse-Medium Sand, Decomposed Vegetation
2	ML		Very Soft, Grey Fine Sandy Silt, Trace Clay, Decomposed Vegetation
3	ML	561.3	Very Soft, Grey Fine Sandy Silt, Trace Clay, Decomposed Vegetation & Coarse Gravel
4	SW	558.3	Loose, Grey Medium-Fine Sand, Trace Coarse Sand & Coarse Gravel
5	SW-GM		Medium Compact, Grey Gravelly Coarse-Fine Sand, Little Silt, Trace Clay, Tillike (Slightly Bonded In Situ)
6	GW	548.3	Medium Compact, Grey Sandy Coarse-Fine Gravel
7	SM		Very Compact, Grey Silty Fine Sand
8	ML-SM	539.3	Very Compact, Grey Fine Sandy Silt

1⅜" Split Spoon (I.D.) 7-22-75

570 — 560 — 550 — 540

REVETMENT

NOTES

1. For boring locations see Plate 1

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
BUFFALO, NEW YORK 14207

DRAWN BY D. M. P.
DESIGNED BY
CHECKED BY
SUBMITTED BY
CHIEF, TECHNICAL BRANCH
APPROVAL RECOMMENDED
CHIEF, ENGINEERING DIVISION

CATTARAUGUS CREEK HARBOR, N. Y.

LOGS OF EXPLORATIONS
CHANNEL, REVETMENT & BERM

APPROVED — DATE
COL. C. E. DISTRICT ENGINEER

SCALE AS SHOWN

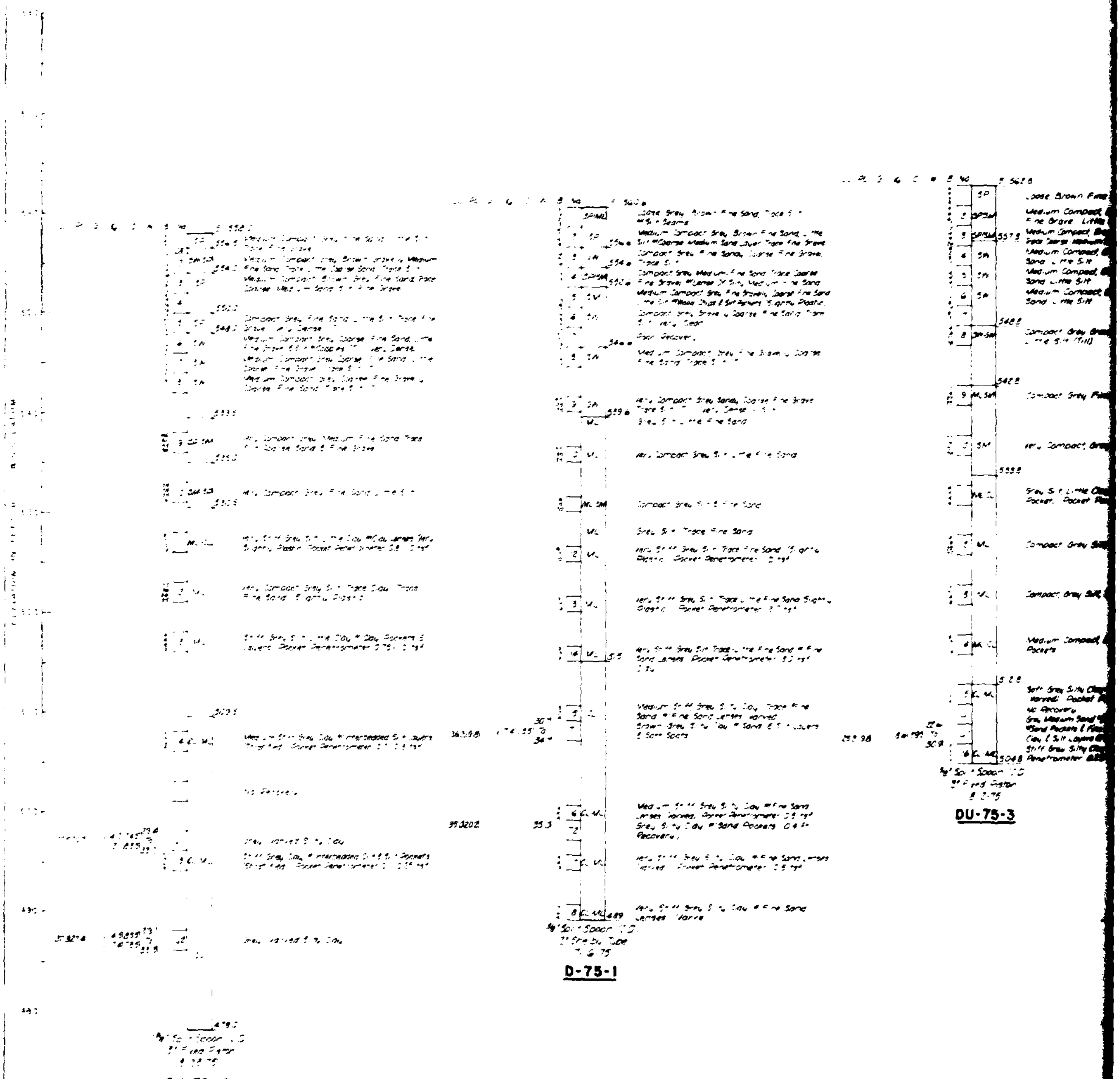
MOFFATT & NICHOL ENGINEERS
LONG BEACH, CALIFORNIA
ARCHITECT - ENGINEER

TO ACCOMPANY SPECIFICATIONS SERIAL NO. DACW 49 - 7 - B - 00

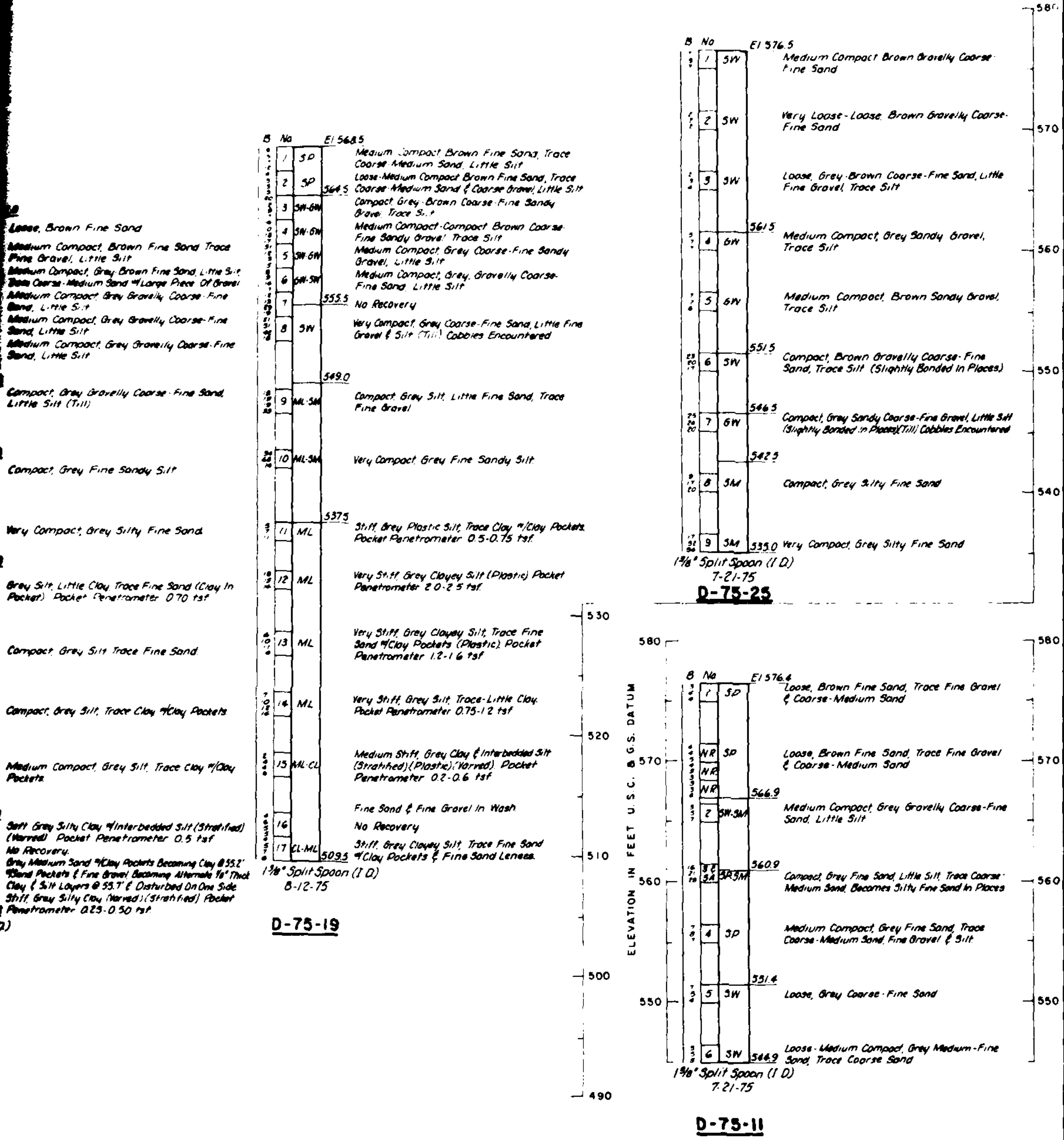
DRAWING NUMBER

SHEET OF

PLATE



NORTH BREAKWATER



NOTES

1. For boring locations, see Plate 1
2. For Legend for Logs of Explorations, see Plate C2.
3. "C" was obtained from taking half of the unconfined compressive strength value.

ATER

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
BUFFALO, NEW YORK 14207

DRAWN BY D. M. P.
DESIGNED BY
CHECKED BY
SUBMITTED BY
CHIEF, TECHNICAL BRANCH
APPROVAL RECOMMENDED
CHIEF, ENGINEERING DIVISION

CATTARAUGUS CREEK HARBOR, N. Y.

LOGS OF EXPLORATIONS
NORTH BREAKWATER

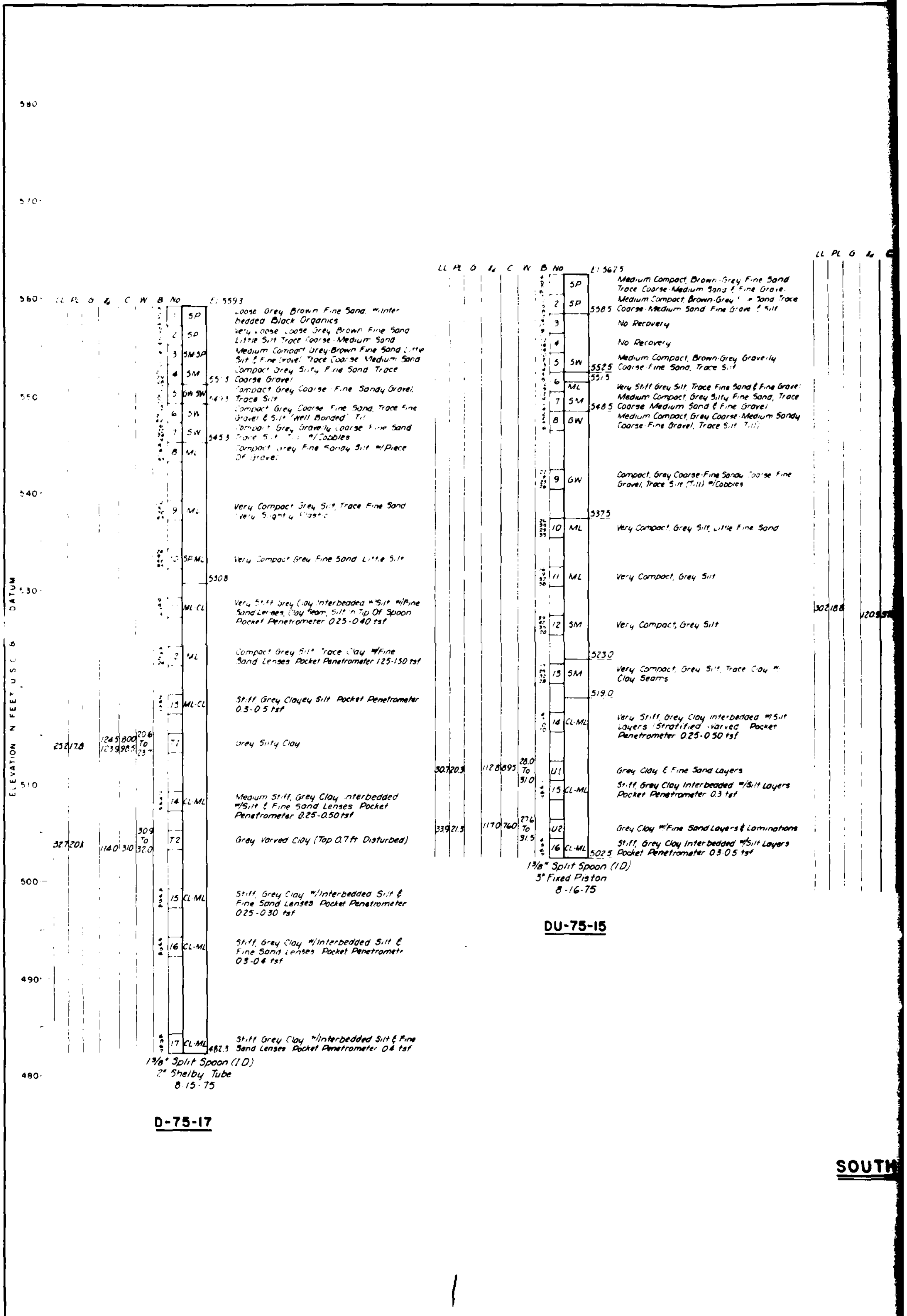
APPROVED DATE
COL. C. E. DISTRICT ENGINEER
SCALE AS SHOWN

MOFFATT & NICHOL, ENGINEERS
LONG BEACH, CALIFORNIA
ARCHITECT - ENGINEER

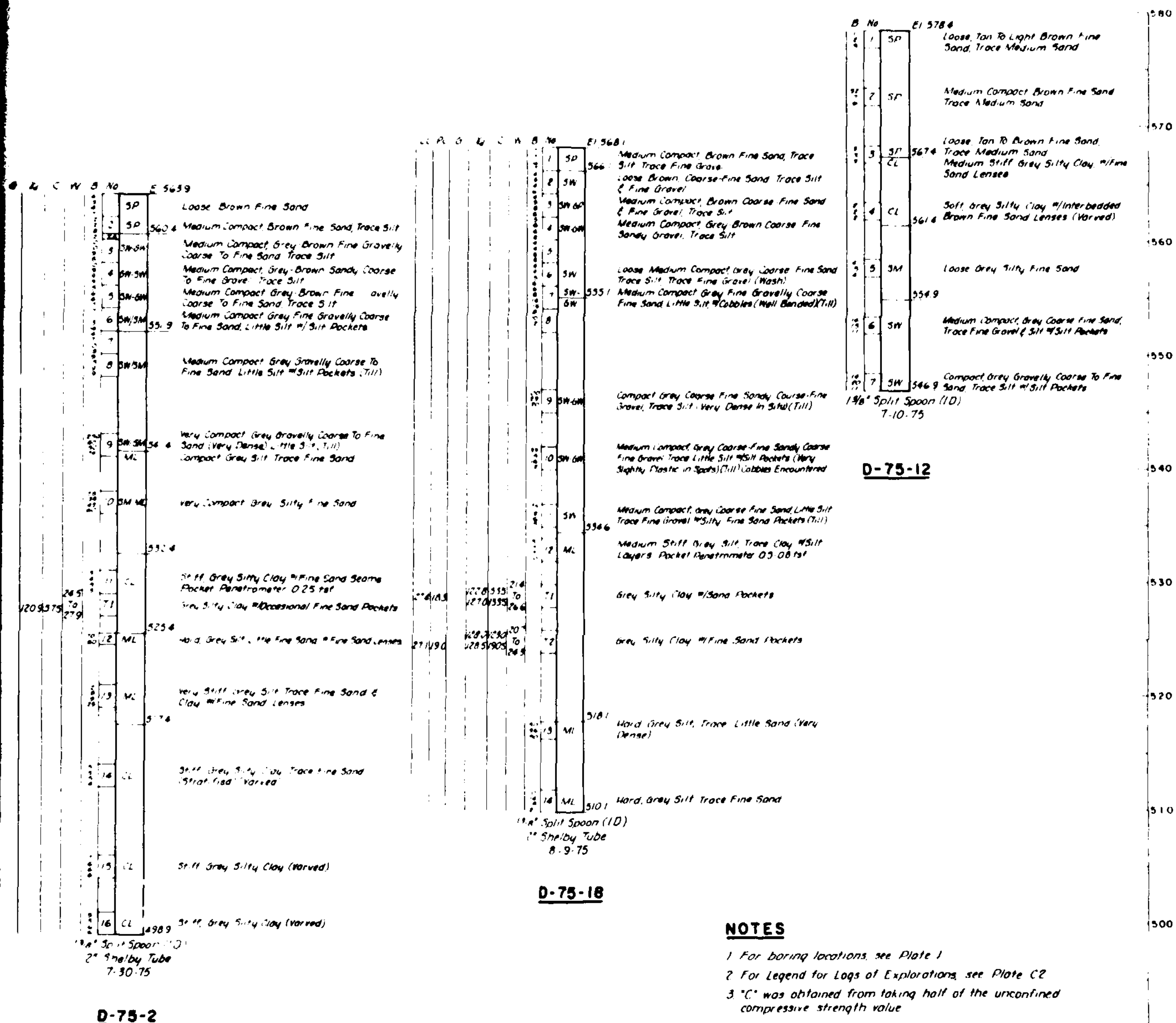
TO ACCOMPANY SPECIFICATIONS SERIAL
NO. DACW 49 7 8 00

DRAWING NUMBER
SHEET OF

PLATE C3



ELEVATION IN FEET U.S.C. & G. DATUM
580
570
560
550
540
530
510
500
490
480
LL PL G Ya C W B No
El. 559.3
Loose Grey Brown Fine Sand w/Interbedded Black Organics
Very Loose-Loose Grey Brown Fine Sand Little Silt Trace Coarse-Medium Sand
Medium Compact Grey-Brown Fine Sand Little Silt & Fine Gravel Trace Coarse-Medium Sand
Compact Grey Silty Fine Sand Trace Coarse Gravel
Compact Grey Coarse-Fine Sandy Gravel, Trace Silt
Compact Grey Coarse-Fine Sand, Trace Fine Gravel & Silt (Well Bonded" Till
Compact Grey Gravelly Coarse-Fine Sand Trace Silt w/Cobbles
Compact Grey Fine Sandy Silt w/Piece Of Gravel
Very Compact Grey Silt, Trace Fine Sand (Very Slightly Plastic)
Very Compact Grey Fine Sand Little Silt
Very Stiff Grey Clay Interbedded w/Silt w/Fine Sand Lenses, Clay Seam, Silt In Tip Of Spoon Pocket Penetrometer 0.25-0.40 tsf
Compact Grey Silt Trace Clay w/Fine Sand Lenses Pocket Penetrometer 1.25-1.50 tsf
Stiff Grey Clayey Silt Pocket Penetrometer 0.3-0.5 tsf
Grey Silty Clay
Medium Stiff, Grey Clay Interbedded w/Silt & Fine Sand Lenses Pocket Penetrometer 0.25-0.50 tsf
Grey Varved Clay (Top 0.7 ft Disturbed)
Stiff Grey Clay w/Interbedded Silt & Fine Sand Lenses Pocket Penetrometer 0.25-0.30 tsf
Stiff Grey Clay w/Interbedded Silt & Fine Sand Lenses Pocket Penetrometer 0.3-0.4 tsf
Stiff Grey Clay w/Interbedded Silt & Fine Sand Lenses Pocket Penetrometer 0.4 tsf
482.3
1 3/8" Split Spoon (I.D.)
2" Shelby Tube
8-15-75
D-75-17
El. 567.5
Medium Compact, Brown-Grey Fine Sand Trace Coarse-Medium Sand & Fine Gravel
Medium Compact Brown-Grey Fine Sand Trace Coarse-Medium Sand Fine Gravel & Silt
No Recovery
No Recovery
Medium Compact, Brown-Grey Gravelly Coarse-Fine Sand, Trace Silt
Very Stiff Grey Silt, Trace Fine Sand & Fine Gravel
Medium Compact Grey Silty Fine Sand, Trace Coarse-Medium Sand & Fine Gravel
Medium Compact, Grey Coarse-Medium Sandy Coarse-Fine Gravel, Trace Silt (Till)
Compact, Grey Coarse-Fine Sandy Coarse-Fine Gravel, Trace Silt (Till) w/Cobbles
Very Compact, Grey Silt, Little Fine Sand
Very Compact, Grey Silt
Very Compact, Grey Silt
Very Compact, Grey Silt, Trace Clay w/Clay Seams
Very Stiff, Grey Clay Interbedded w/Silt Layers (Stratified-Varved) Pocket Penetrometer 0.25-0.50 tsf
Grey Clay & Fine Sand Layers
Stiff, Grey Clay Interbedded w/Silt Layers Pocket Penetrometer 0.3 tsf
Grey Clay w/Fine Sand Layers & Laminations
Stiff, Grey Clay Interbedded w/Silt Layers Pocket Penetrometer 0.3-0.5 tsf
502.5
1 3/8" Split Spoon (I.D.)
3" Fixed Piston
8-16-75
DU-75-15
SOUTH



NOTES

1. For boring locations, see Plate 1
2. For Legend for Logs of Explorations, see Plate C2
3. "C" was obtained from taking half of the unconfined compressive strength value

SOUTH BREAKWATER

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
BUFFALO NEW YORK 14207

DRAWN BY D.M.P.
DESIGNED BY
CHECKED BY
SUBMITTED BY
CHIEF TECHNICAL BRANCH
APPROVAL RECOMMENDED
CHIEF ENGINEERING DIVISION

CATTARAUGUS CREEK HARBOR, N.Y.

LOGS OF EXPLORATIONS
SOUTH BREAKWATER

APPROVED — DATE
COL. C.E. DISTRICT ENGINEER

SCALE AS SHOWN

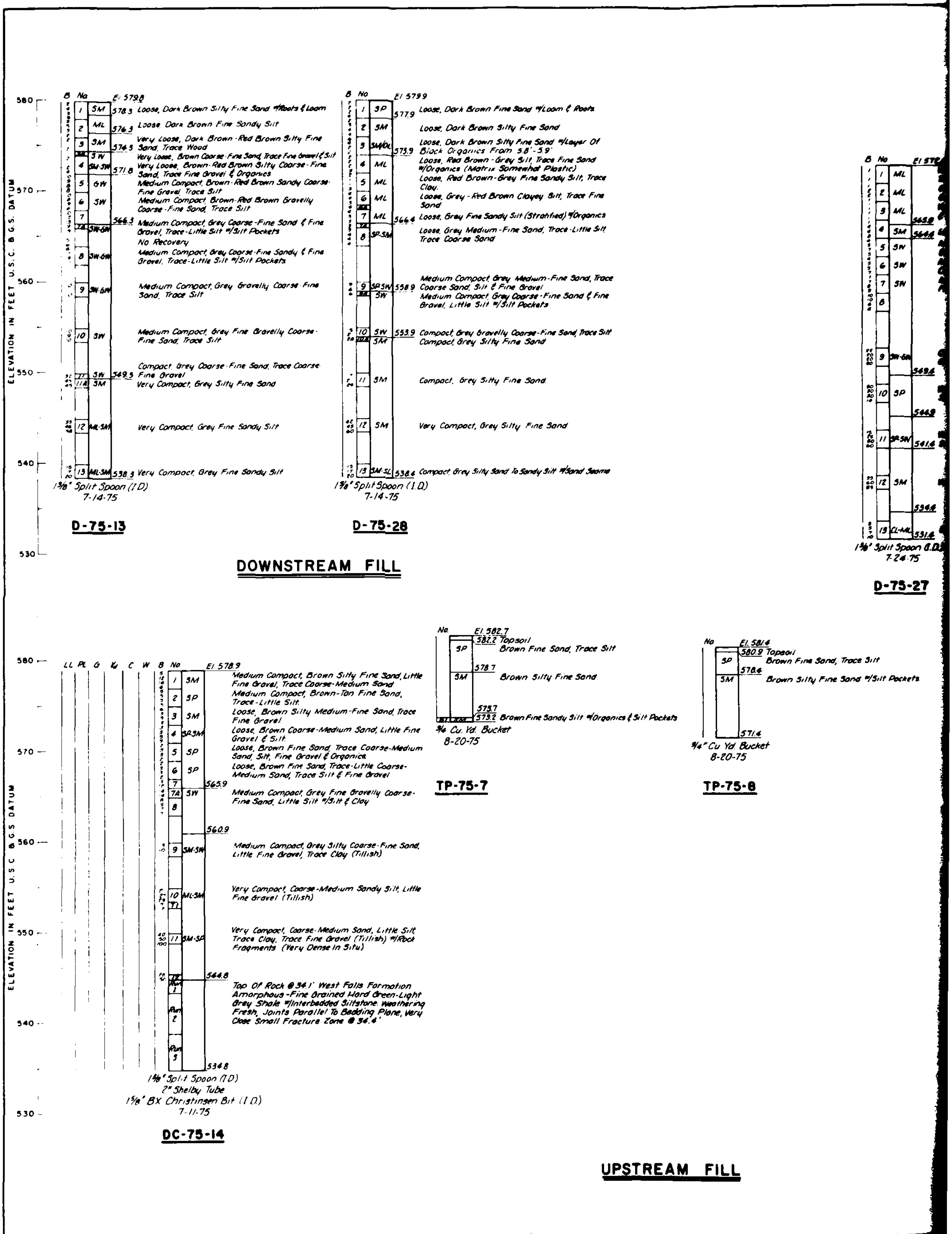
MOFFATT & NICHOL ENGINEERS
LONG BEACH, CALIFORNIA
ARCHITECT - ENGINEER

TO ACCOMPANY SPECIFICATIONS SERIAL NO. DACW 49-7 -R-00

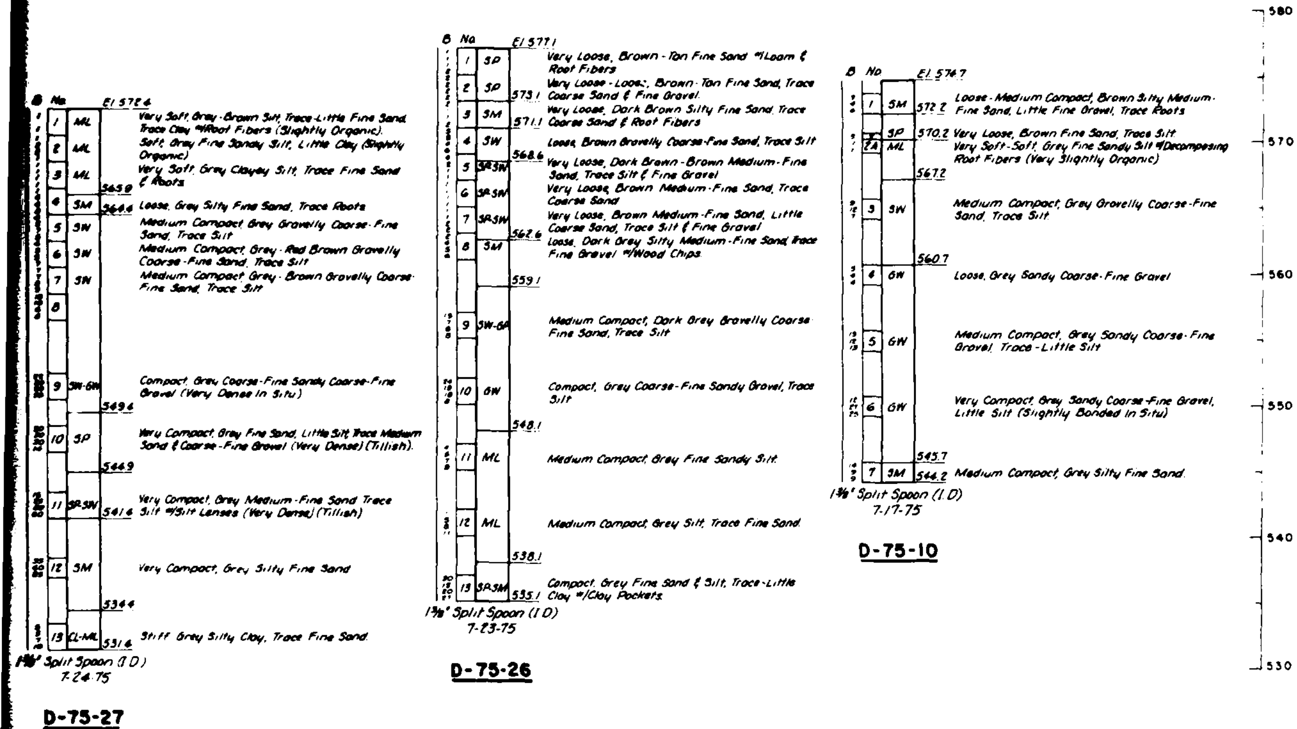
DRAWING NUMBER

SHEET OF

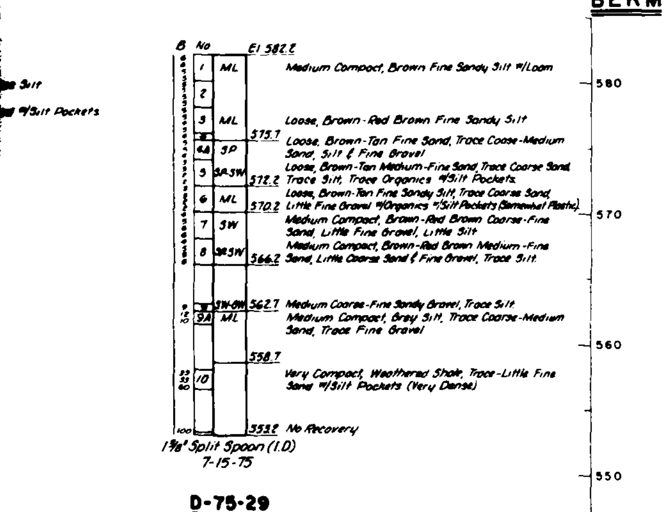
PLATE C4

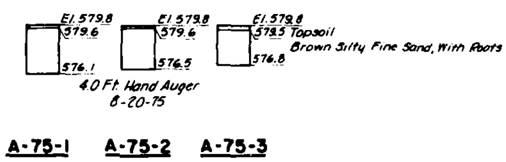


ELEVATION IN FEET U.S.C. & G.S. DATUM
580
570
560
550
540
530
B No El. 579.8
SM 578.3 Loose, Dark Brown Silty Fine Sand w/Roots & Loam
ML 576.3 Loose Dark Brown Fine Sandy Silt
SM 574.3 Very Loose, Dark Brown-Red Brown Silty Fine Sand, Trace Wood
SW Very Loose, Brown Coarse-Fine Sand, Trace Fine Gravel & Silt
SM-SW 571.8 Very Loose, Brown-Red Brown Silty Coarse-Fine Sand, Trace Fine Gravel & Organics
GW Medium Compact, Brown-Red Brown Sandy Coarse-Fine Gravel, Trace Silt
SW Medium Compact, Brown-Red Brown Gravelly Coarse-Fine Sand, Trace Silt
566.3 Medium Compact, Grey Coarse-Fine Sand & Fine Gravel, Trace-Little Silt w/Silt Pockets
SW-GW
No Recovery
SW-GW Medium Compact, Grey Coarse-Fine Sandy & Fine Gravel, Trace-Little Silt w/Silt Pockets
SW-GW Medium Compact, Grey Gravelly Coarse-Fine Sand, Trace Silt
SW Medium Compact, Grey Fine Gravelly Coarse-Fine Sand, Trace Silt
SW 549.3 Compact, Grey Coarse-Fine Sand, Trace Coarse-Fine Gravel
SM Very Compact, Grey Silty Fine Sand
ML-SM Very Compact, Grey Fine Sandy Silt
ML-SM 538.3 Very Compact, Grey Fine Sandy Silt
1⅜" Split Spoon (I.D.)
7-14-75
D-75-13
B No El. 579.9
SP 577.9 Loose, Dark Brown Fine Sand w/Loam & Roots
SM Loose, Dark Brown Silty Fine Sand
SM/OL 575.9 Loose, Dark Brown Silty Fine Sand w/Layer Of Black Organics From 5.8'-5.9'
ML Loose, Red Brown-Grey Silt, Trace Fine Sand w/Organics (Matrix Somewhat Plastic)
ML Loose, Red Brown-Grey Fine Sandy Silt, Trace Clay
ML Loose, Grey-Red Brown Clayey Silt, Trace Fine Sand
ML 566.4 Loose, Grey Fine Sandy Silt (Stratified) w/Organics
SP-SM Loose, Grey Medium-Fine Sand, Trace-Little Silt Trace Coarse Sand
SP-SW 558.9 Medium Compact, Grey Medium-Fine Sand, Trace Coarse Sand, Silt & Fine Gravel
SW Medium Compact, Grey Coarse-Fine Sand & Fine Gravel, Little Silt w/Silt Pockets
SW 553.9 Compact, Grey Gravelly Coarse-Fine Sand, Trace Silt
SM Compact, Grey Silty Fine Sand
SM Compact, Grey Silty Fine Sand
SM Very Compact, Grey Silty Fine Sand
SM-SL 538.4 Compact Grey Silty Sand To Sandy Silt w/Sand Seams
1⅜" Split Spoon (I.D.)
7-14-75
D-75-28
DOWNSTREAM FILL
B No El. 579
ML
ML
ML
SM 565.9
SM 564.4
SW
SW
SW
SW-GW 549.4
SP 546.9
SP-SW 541.4
SM 536.4
CL-ML 531.4
1⅜" Split Spoon (I.D.)
7-24-75
D-75-27
LL PL G W C W B No El. 578.9
SM Medium Compact, Brown Silty Fine Sand, Little Fine Gravel, Trace Coarse-Medium Sand
SP Medium Compact, Brown-Tan Fine Sand, Trace-Little Silt
SM Loose, Brown Silty Medium-Fine Sand, Trace Fine Gravel
SP-SM Loose, Brown Coarse-Medium Sand, Little Fine Gravel & Silt
SP Loose, Brown Fine Sand, Trace Coarse-Medium Sand, Silt, Fine Gravel & Organics
SP Loose, Brown Fine Sand, Trace-Little Coarse-Medium Sand, Trace Silt & Fine Gravel
565.9
SW Medium Compact, Grey Fine Gravelly Coarse-Fine Sand, Little Silt w/Silt & Clay
560.9
SM-SW Medium Compact, Grey Silty Coarse-Fine Sand, Little Fine Gravel, Trace Clay (Tillish)
ML-SM Very Compact, Coarse-Medium Sandy Silt, Little Fine Gravel (Tillish)
SM-SP Very Compact, Coarse-Medium Sand, Little Silt Trace Clay, Trace Fine Gravel (Tillish) w/Rock Fragments (Very Dense In Situ)
544.8
Top Of Rock @ 34.1' West Falls Formation Amorphous-Fine Grained Hard Green-Light Grey Shale w/Interbedded Siltstone. Weathering Fresh, Joints Parallel To Bedding Plane, Very Close Small Fracture Zone @ 34.4'
Run 1
Run 2
Run 3
534.8
1⅜" Split Spoon (I.D.)
2" Shelby Tube
1⅝" BX Christinsen Bit (I.D.)
7-11-75
DC-75-14
No. El. 582.7
582.2 Topsoil
SP Brown Fine Sand, Trace Silt
578.7
SM Brown Silty Fine Sand
573.7
573.2 Brown Fine Sandy Silt w/Organics & Silt Pockets
¾ Cu. Yd. Bucket
8-20-75
TP-75-7
No. El. 581.4
580.9 Topsoil
SP Brown Fine Sand, Trace Silt
578.4
SM Brown Silty Fine Sand w/Silt Pockets
571.4
¾" Cu. Yd. Bucket
8-20-75
TP-75-8
UPSTREAM FILL



BERM





DOWNSTREAM FILL

NOTES

1. For boring locations, see Plate 1.
2. For Legend for Logs of Explorations, see Plate C2.

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, BUFFALO
CORPS OF ENGINEERS
BUFFALO NEW YORK 14207

DRAWN BY D.M.P.
DESIGNED BY
CHECKED BY
SUBMITTED BY
CHIEF TECHNICAL BRANCH
APPROVAL RECOMMENDED
CHIEF ENGINEERING DIVISION

CATTARAUGUS CREEK HARBOR, N.Y.

LOGS OF EXPLORATIONS
FILLS & BERM

APPROVED DATE
COL C E DISTRICT ENGINEER

SCALE AS SHOWN

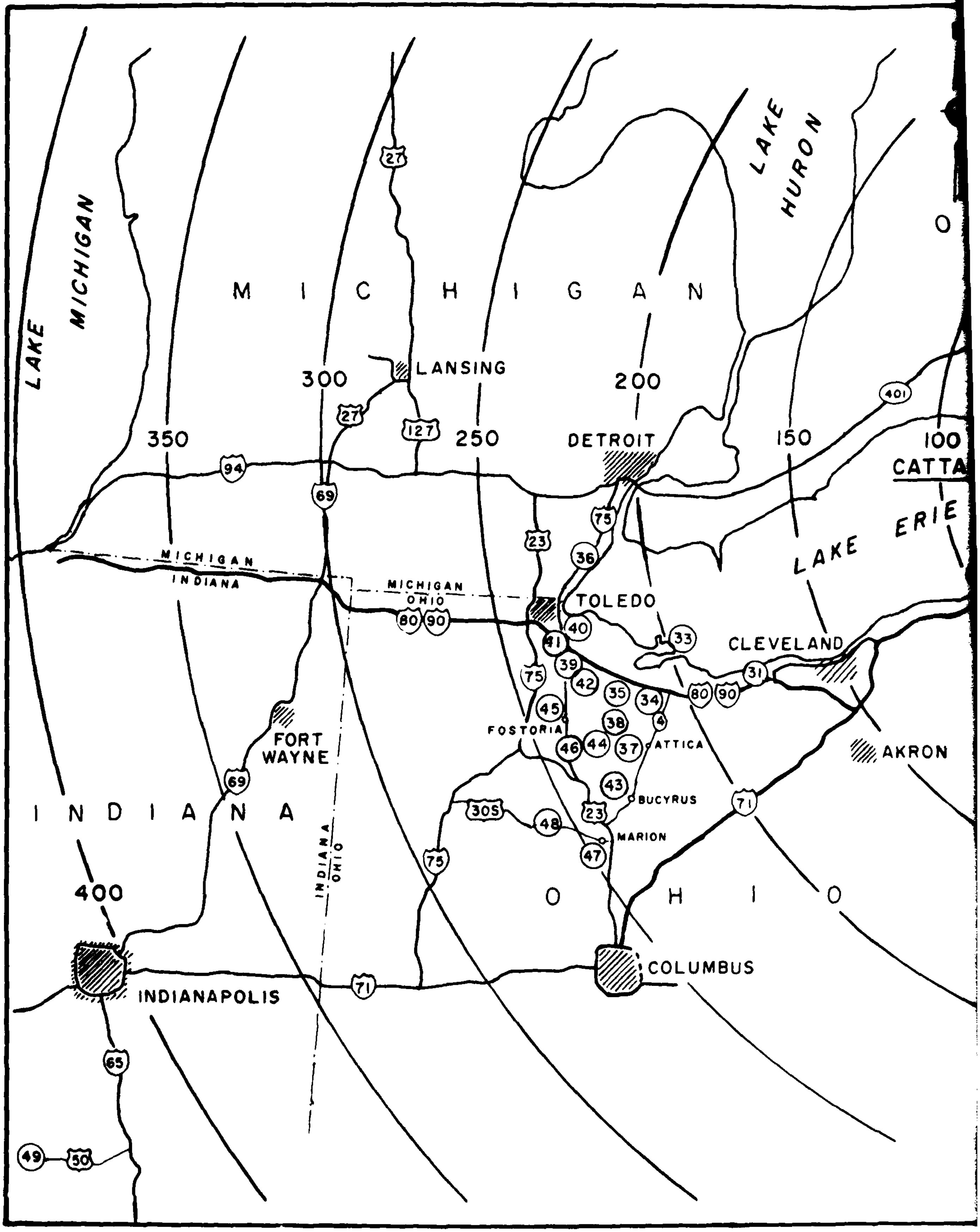
MOFFATT & NICHOL, ENGINEERS
LONG BEACH, CALIFORNIA
ARCHITECT - ENGINEER

TO ACCOMPANY SPECIFICATIONS SERIAL NO DACW 49 7 8 00

DRAWING NUMBER

SHEET OF

PLATE C5



LAKE MICHIGAN
LAKE HURON
MICHIGAN
LANSING
300
200
350
250
DETROIT
150
100
CATTA
LAKE ERIE
MICHIGAN
INDIANA
MICHIGAN
OHIO
TOLEDO
CLEVELAND
AKRON
FORT WAYNE
FOSTORIA
ATTICA
BUCYRUS
MARION
INDIANA
INDIANA
OHIO
400
OHIO
COLUMBUS
INDIANAPOLIS
27
127
94
69
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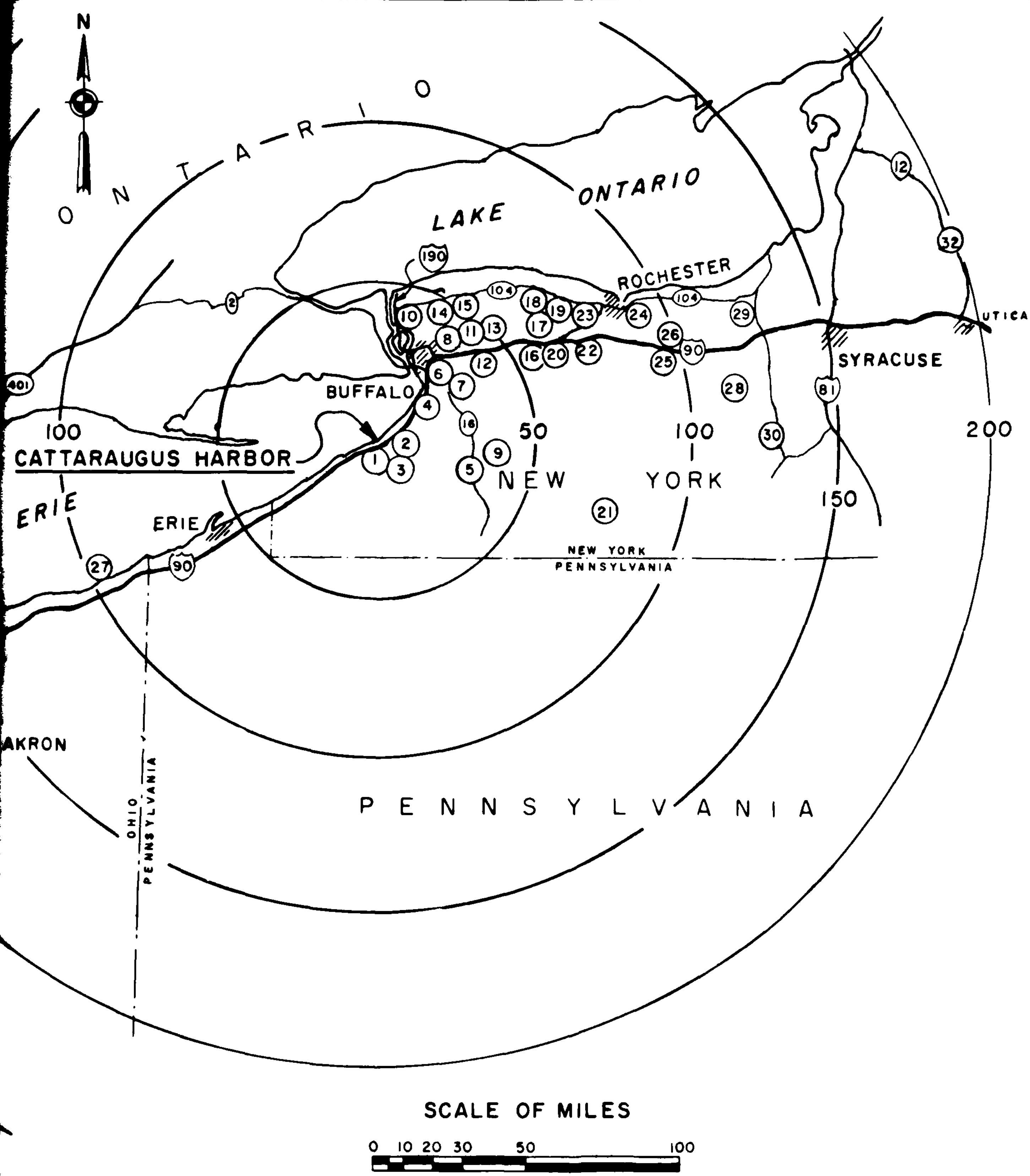
49
50



NOTES:
1. NU
QUAR
2. FOR
PROD
SHEE

CA

POS
U.
TO AC

NOTES:

1. NUMBER IN CIRCLE INDICATES QUARRY SITE.
2. FOR QUARRY NAMES AND PRODUCTS SEE MAP SUPPLEMENT SHEET.

CATTARAUGUS HARBOR, N.Y.

LOCATION MAP
POSSIBLE MATERIAL SOURCES

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

PLATE C6

/

MAP SUPPLEMENT SHEET SUMMARY OF POSSIBLE SOURCES FOR CONSTRUCTION MATERIALS										
SITE NUMBER	SOURCE	QUARRY OR PIT LOCATION	RADIAL DISTANCE	A6	A4	A3	A1	B6, B4, B3	C1, F2	B1, B5
1	HANOVER SAND AND GRAVEL	HANOVER, NY	5							
2	GERNATT GRAVEL PRODUCTS	COLLINS, NY	12							
3	COUNTRY SIDE SAND AND GRAVEL	COLLINS, NY	13							
4	ERIE SAND AND GRAVEL	LACKAWANNA, NY	25							
5	BUFFALO SLAG CO.	MACHAIS, NY	35							
6	PINE HILL CONCRETE MIX CO.	LANCASTER, NY	32							
7	FEDERAL CRUSHED STONE CO.	CHEEKTOWAGA, NY	37				X	X	X	X
8	HOUDAILLE CONST. MTLS.	CLARENCE, NY	42				X	X	X	X
9	SPENCER AND HALEY, INC.	FREEDOM, NY	43							
10	NIAGARA STONE DIVISION	NIAGARA FALLS, NY	43	X	X	X	X	X	X	X
11	LANCASTER STONE PRODUCTS	CLARENCE, NY	46				X	X	X	X
12	COUNTY LINE STONE CO.	AKRON, NY	48		X	X	X	X	X	X
13	PINE HILL CONCRETE MIX CO.	NEWSTEAD, NY	50							
14	FRONTIER STONE PRODUCTS	LOCKPORT, NY	50	X	X	X	X	X	X	X
15	ROYALTON STONE PRODUCTS	GASPORT, NY	55	X	X	X	X	X	X	X
16	GENESEE STONE PRODUCTS	STAFFORD, NY	64		X	X	X	X	X	X
17	MEDINA SANDSTONE, INC.	HULBERTON, NY	72	X	X	X				
18	B. R. DEWITT	RIDGEWAY, NY	73							
19	CONCRETE MATERIALS, INC.	SWEDEN, NY	77		X	X	X	X	X	X
20	VALLEY SAND AND GRAVEL CORP.	SCOTTVILLE, NY	77							
21	BUFFALO SLAG CO.	ALFRED STATION, NY	79							
22	GENERAL CRUSHED STONE, INC.	HONEOYE, NY	80		X	X	X	X	X	X
23	DOLOMITE PRODUCTS, INC.	GATES CENTER, NY	82				X	X	X	X
24	DOLOMITE PRODUCTS, INC.	PENFIELD, NY	92	X	X	X	X	X	X	X
25	CONCRETE MATERIALS, INC.	MANCHESTER, NY	95		X	X	X	X	X	X
26	A. CLEASON	PALMYRA, NY	103							
27	R. W. SIDLEY CO.	THOMPSON, OH	118							

		X	X	X	X			X			X	X	X		X	X	X		X	X							B.1, R.5
X	X					X	X		X					X				X			X	X	X	X	X	X	F1
													X		X	X	X		X	X							COARSE AGGREGATE
X						X	X		X					X				X			X	X	X	X	X	X	FINE AGGREGATE

26	A. GLEASON	PALMYRA, NY	105							
27	R. W. SIDLEY CO.	THOMPSON, OH	118							
28	WARREN BROS.	CANOGA, NY	122		X	X	X	X	X	X
29	GENERAL CRUSHED STONE, INC.	SODUS, NY	132			X	X	X	X	X
30	CAYUGA CRUSHED STONE CO.	SOUTH LANSING, NY	133						X	X
31	CLEVELAND QUARRIES	SOUTH AMHERST, OH	171	X						
32	EASTERN ROCK PRODUCTS	BOONEVILLE, NY	200							
33	STANDARD SLAG CO.	MARBLEHEAD, OH	191		X	X	X	X	X	X
34	FRANCE STONE CO.	FLAT ROCK, OH	204		X	X				
35	FRANCE STONE CO.	BELLEVUE, OH	211		X	X				
36	FRANCE STONE CO.	MONROE, MI	213	X	X	X				
37	FRANCE STONE CO.	BLOOMVILLE, OH	215	X	X	X				
38	SANDUSKY CRUSHED STONE	PARKERTOWN, OH	219		X	X				
39	U. S. GYPSUM CO.	GENOA, OH	220	X	X	X				
40	E. KRAEMER AND SON, INC.	CLAY CENTER, OH	220	X	X	X				
41	WOODVILLE LIME AND CHEMICAL CO.	WOODVILLE, OH	222	X	X	X				
42	CHAS. PFIZER, INC.	GIBSONBURG, OH	223	X	X	X				
43	NATIONAL LIME AND STONE CO.	SPORE, OH	225	X	X	X				
44	WYANDOT DOLOMITE, INC.	CAREY, OH	229	X	X	X				
45	BROUGH STONE CO.	WEST MILLGROVE, OH	233	X	X	X				
46	NATIONAL LIME AND STONE CO.	CAREY, OH	235	X	X	X				
47	NATIONAL LIME AND STONE CO.	MARION, OH	240	X	X	X				
48	TRI COUNTY LIMESTONE CO.	MARSEILLES, OH	252	X	X	X				
49	INDIANA LIMESTONE	BEDFORD, IND	452	X	X	X				

NOTE:

TYPE A6 STONE	ARMOR STONE	4-12 TONS
TYPE A4 STONE	ARMOR STONE	2.5-8 TONS
TYPE A3 STONE	ARMOR STONE	2-6 TONS
TYPE A1 STONE	ARMOR STONE	3/4-2 TONS
TYPE B6 STONE	UNDERLAYER STONE	600-2,400 LBS.
TYPE B4 STONE	UNDERLAYER STONE	400-1,600 LBS.
TYPE B3 STONE	UNDERLAYER STONE	300-1,200 LBS.
TYPE C1 STONE	CORE STONE	1 In.-1,000 LBS.
TYPE B.1 STONE	RIPRAP STONE	100- 400 LBS.
TYPE R.5 STONE	RIPRAP STONE	250-4,000 LBS.
TYPE F1 STONE	FILTER STONE	#10 SIEVE-12 INCHES
TYPE F2 STONE	FILTER STONE	.5- 20 INCHES
	COARSE AGGREGATE	1/2 - 1-1/2 INCH
	FINE AGGREGATE	#200 SIEVE-3/8 INCH

X INDICATES THIS SOURCE IS CAPABLE OF PRODUCING THAT SIZE STO

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

PLATE C7

			X		X
X	X	X			
X	X	X			
	X	X			
			X		X
X	X	X	X	X	X

TONS
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2 INCH
INCH

ZE STONE.

POSSIBLE SOURCES FOR COARSE AGGREGATE FOR CLASS A

SOURCE	ROCK TYPE	PROPOSED USE
FEDERAL CRUSHED STONE DIVISION OF BUFFALO SLAG QUARRY AT CHEEKTOWAGA, N. Y. OFFICE AT BUFFALO, N. Y.	ONONDAGA FORMATION (LIMESTONE)	COARSE AGGREGATE
HOUDAILLE CONSTRUCTION MATERIALS, INC. QUARRY AT CLARENCE, N. Y. OFFICE AT CLARENCE, N. Y.	ONONDAGA FORMATION (LIMESTONE)	COARSE AGGREGATE
LANCASTER STONE PRODUCTS CORP. QUARRY AT CLARENCE, N. Y. OFFICE AT WILLIAMSVILLE, N. Y.	ONONDAGA FORMATION (LIMESTONE)	COARSE AGGREGATE
NIAGARA STONE DIVISION OF GREATER BUFFALO PRESS INC. QUARRY AT NIAGARA FALLS, N. Y. OFFICE AT NIAGARA FALLS, N. Y.	LOCKPORT FORMATION (DOLOMITE)	COARSE AGGREGATE
COUNTY LINE STONE CO., INC. QUARRY AT AKRON, N. Y. OFFICE AT AKRON, N. Y.	ONONDAGA FORMATION (LIMESTONE)	COARSE AGGREGATE
FRONTIER STONE PRODUCTS, INC. QUARRY AT LOCKPORT, N. Y. OFFICE AT LOCKPORT, N. Y.	LOCKPORT FORMATION (DOLOMITE)	COARSE AGGREGATE
ROYALTON STONE PRODUCTS, INC. QUARRY AT GASPORT, N. Y. OFFICE AT GASPORT, N. Y.	LOCKPORT FORMATION (DOLOMITE LIMESTONE)	COARSE AGGREGATE

R CLASS A AND CLASS B CONCRETE

USE	RADIAL DISTANCE	LABORATORY TEST RECORD			
		DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	
E	37 M.	APRIL 1973	ORD LAB LAB # 103/73.3370	BLACK ROCK LOCK REHABILITATION	MAY
E	42 M.	APRIL 1970	NYS DOT LAB # 69AR139	UNKNOWN	UNK
E	46 M.	APRIL 1970	NYS DOT LAB # 70AR2	UNKNOWN	UNK
E	43 M.	APRIL 1970	NYS DOT LAB # 70AR1	UNKNOWN	UNK
E	48 M.	APRIL 1970	NYS DOT LAB # 69AR138	UNKNOWN	UNK
E	50 M.	APRIL 1970	NYS DOT LAB # 70AR7	UNKNOWN	UNK
E	55 M.	APRIL 1970	NYS DOT LAB # 70AR8	UNKNOWN	UNK

SERVICE RECORD			
DATE USED	PROJECT	EVALUATION	
MAY 1973	BLACK ROCK LOCK REHABILITATION	TOO EARLY TO EVALUATE	TYPE II,
UNKNOWN	UNKNOWN	UNKNOWN	TYPE II,
UNKNOWN	UNKNOWN	UNKNOWN	TYPE II, QUARRYI
UNKNOWN	UNKNOWN	UNKNOWN	TYPE II, QUARRYI
UNKNOWN	UNKNOWN	UNKNOWN	TYPE II, QUARRYI
UNKNOWN	UNKNOWN	UNKNOWN	TYPE II, CEMENT
UNKNOWN	UNKNOWN	UNKNOWN	TYPE I A

REMARKS
TYPE II, LOW ALKALI CEMENT REQUIRED.
TYPE II, LOW ALKALI CEMENT REQUIRED. SELECTIVE QUARRYING REQUIRED.
TYPE II, LOW ALKALI CEMENT REQUIRED FOR CHERT ZONES. SELECTIVE QUARRYING MAY BE REQUIRED.
TYPE II, LOW ALKALI CEMENT REQUIRED FOR CHERT ZONES. SELECTIVE QUARRYING REQUIRED.
TYPE II, LOW ALKALI CEMENT REQUIRED FOR CHERT ZONES. SELECTIVE QUARRYING REQUIRED.
TYPE II, LOW ALKALI CEMENT REQUIRED FOR CHERT ZONES. TYPE I CEMENT PERMITTED FOR NON CHERT ZONES.
TYPE I AND II CEMENT PERMITTED.

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	ROCK TYPE	PROPOSED USE	RAD DIST[illegible]
NIAGARA STONE DIV. OF GREAT LAKES COLOR PRINTING CORP. QUARRY AT NIAGARA FALLS, NY (PLETCHERS CORNERS) OFFICE AT NIAGARA FALLS, NY.	LOCKPORT FORMATION (DOLOMITE)	TYPE A6, A4, A3	[illegible]
COUNTY LINE STONE CO, INC. QUARRY AT AKRON, NY OFFICE AT AKRON, NY	ONONDAGA FORMATION (LIMESTONE)	TYPE A4, A3	4[illegible]
FRON[illegible] STONE PRODUCTS, INC. QUARRY AT LOCKPORT, NY OFFICE AT LOCKPORT, NY	LOCKPORT FORMATION (DOLOMITE)	TYPE A6, A4, A3	5[illegible]
ROYALTON STONE PRODUCTS, INC. QUARRY AT GASPORT, NY OFFICE AT GASPORT, NY	LOCKPORT FORMATION (DOLOMITE)	TYPE A6, A4, A3	5[illegible]
GENESEE STONE PRODUCTS CORP. QUARRY AT STAFFORD, NY OFFICE AT BATAVIA, NY	ONONDAGA FORMATION (LIMESTONE)	TYPE A4, A3.	6[illegible]
MEDINA SANDSTONE QUARRY INC. DIVISION OF GREATER BUFFALO PRESS CO. QUARRY AT HULBERTON, NY OFFICE AT BUFFALO, NY	GRIMSBY FORMATION (SANDSTONE)	TYPE A6, A4, A3	7[illegible]
GENERAL CRUSHED STONE CO. QUARRY AT HONEOYE FALLS, NY OFFICE AT EASTON, PA	ONONDAGA FORMATION (LIMESTONE)	TYPE A4, A3	8[illegible]
CONCRETE MATERIALS, INC. QUARRY AT SWEDEN, NY OFFICE AT SWEDEN, NY	LOCKPORT DOLOMITE	TYPE A4, A3	7[illegible]
DOLOMITE PRODUCTS QUARRY AT PENFIELD, NY OFFICE AT PENFIELD, NY	LOCKPORT FORMATION (DOLOMITE)	TYPE A6, A4, A3	9[illegible]
	/		

POSSIBLE SOURCES FOR TYPE A6, A4, A3, (ARMOR STONE)

RADIAL DISTANCE	LABORATORY TEST RECORD			
	DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	DATE
43 M.	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA NO. 2 (RIPRAP)	UNKNOWN
48 M.	MAY 1967	ORD LAB LAB # 103/67.605C	WARSAW, NY. FLOOD CONTROL PROJECT (RIPRAP)	1967
	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA NO. 2 (RIPRAP)	1971
	SEPTEMBER 1974	ORD LAB	CONFINED DREDGE SPOIL DISPOSAL AREAS. NOS. 1 AND 2 BUFFALO HARBOR, NY (REPAIRS)	
50 M.	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA NO. 2 (RIPRAP)	UNKNOWN
	AUGUST 1974	UNKNOWN	CONFINED DIKE DISPOSAL PROGRAM, BUFFALO HARBOR, NY. SITE 4 (ARMOR STONE)	UNKNOWN
55 M.	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA NO. 2 (RIPRAP)	UNKNOWN
64 M.	DECEMBER 1971	ORD LAB LAB # 103/72.602C	WELLSVILLE RECTIFICATION PROJECT, WELLSVILLE, NY (RIPRAP)	UNKNOWN
72 M.	JUNE 1973	ORD LAB LAB #	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	1932
80 M.	DECEMBER 1971	ORD LAB LAB # 103/72.602C	WELLSVILLE RECTIFICATION PROJECT, WELLSVILLE, NY (RIPRAP)	1971
77 M.	JANUARY 1971	ORD LAB LAB # 101/71.362C	ROCHESTER HARBOR, NY EAST PIER REPAIRS	1971
92 M.	UNKNOWN	UNKNOWN	BUFFALO DIKED DISPOSAL AREA NO. 2 (RIPRAP)	UNKNOWN
	JUNE 1973	ORD LAB LAB # 103/73.603C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM	UNKNOWN

…E)

…TE USED	SERVICE RECORD		
	PROJECT	EVALUATION	
	UNKNOWN	UNKNOWN	BOTH LIFTS CONSISTE… MEMBERS ACCEPTABLE. RAIL FACILITIES AVAIL… LARGE SIZE MATERIAL…
	WARSAW, NY. FLOOD CONTROL PROJECT (RIPRAP)	APPEARS SATISFACTORY	THE SECOND LIFT ONLY… BOTH MEMBER OF THE …
	BUFFALO DIKED DISPOSAL AREA NO. 2 (RIPRAP)	TOO EARLY TO EVALUATE	ONLY THE SECOND LIFT… AVERAGES 168 P.C.F.
			BOTH FIRST AND SECO…
	UNKNOWN	UNKNOWN	THE DECEW MEMBER NOT… FROM 162 P.C.F. RAIL…
	UNKNOWN	UNKNOWN	ONLY THE GASPORT MEM… ON NYS BARGE CANAL …
	UNKNOWN	UNKNOWN	ONLY MATERIALS FROM … FROM 163 P.C.F. TO 1…
	UNKNOWN	UNKNOWN	ONLY THE FIRST AND S… 168 P.C.F. RAIL FAC…
	NON-GRADED COARSE AGGREGATE FOR CONCRETE, NYS ROUTE 18. CURB STONE AND BUILDING STONE FOR WESTERN NY & ONTARIO, CANADA	EXCELLENT SATISFACTORY	UNIT WEIGHT VARIES F… CANAL READILY ACCESS… TRUCKING FACILITIES …
	WELLSVILLE EMERGENCY FLOOD CONTROL PROJECT (RIPRAP)	SATISFACTORY	QUARRY NOT RESPONSIB… P.C.F. TO 168 P.C.F.
	ROCHESTER HARBOR, NY EAST PIER REPAIRS	SATISFACTORY	SPECIFIC GRAVITY IS 2.75.
	UNKNOWN	UNKNOWN	ONLY THE PENFIELD ME… BER ACCEP. FOR THIS PROJECT. RAIL FACIL… TIES NOT AVAILABLE.
	UNKNOWN	UNKNOWN	UNIT WEIGHT VARIES FROM 163 P.C.F. TO 171 P.C.F.

REMARKS
NSISTING OF OAK ORCHARD, ERAMOSA AND UPPER GOAT ISLAND TABLE. UNIT WEIGHT VARIES FROM 166 P.C.F. TO 174 P.C.F. S AVAILABLE. MANAGEMENT MAY BE RELUCTANT TO PRODUCE TERIAL.
FT ONLY IS APPROVED FOR RIPRAP AND IS FROM THE MOORE- OF THE ONONDAGA FORMATION.
ND LIFT, EAST FACE TESTED FOR THIS PROJECT. UNIT WEIGHT P.C.F. RAIL FACILITIES NOT AVAILABLE.
D SECOND LIFTS ARE BEING TESTED.
BER NOT ACCEPTABLE FOR THIS PROJECT. UNIT WEIGHTS VARY F. RAIL FACILITIFS NOT AVAILABLE.
ORT MEMBER ACCEPTABLE FOR ARMOR STONE. LOADING FACILITIES CANAL TO BE AVAILABLE.
S FROM EAST END OF QUARRY TESTED. UNIT WEIGHT VARIES F. TO 165 P.C.F. RAIL FACILITIFS AVAILABLE.
T AND SECOND LIFT ACCEPTABLE. UNIT WEIGHT AVERAGES AIL FACILITIFS NOT AVAILABLE.
ARIES FROM 153 P.C.F., AVERAGE 156.6 P.C.F. ERIE BARGE ACCESSABLE. NO RAIL FACILITIES OR QUARRY OWNED LITIES (TESTING TO BE COMPLETED 19 JUNE 1973)
SPONSIBLE FOR GRADATION, UNIT WEIGHT VARIES FROM 166 P.C.F. RAIL FACILITIES NOT AVAILABLF.

ITY IS
IELD MEM- R THIS L FACILI- LABLE.
ARIES F. TO

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

PLATE C9

SOURCE	ROCK TYPE	PROPOSED USE	R DI
GENERAL CRUSHED STONE, INC. QUARRY AT SODUS, NY OFFICE AT EASTON, PA	LOCKPORT FORMATION (DOLOMITE)	TYPE A3	
CLEVELAND QUARRIES QUARRY AT SOUTH AMHERST, OH OFFICE AT SOUTH AMHERST, OH	BEREA SANDSTONE	TYPE A6	
STANDARD SLAG CO. QUARRY AT MARBLEHEAD, OH OFFICE AT MARBLEHEAD, OH	LUCAS FORMATION (DOLOMITE)	TYPE A4, A3	
FRANCE STONE CO. QUARRY AT BELLEVUE, OH PFFOCE AT TP:EDP. PJ	COLUMBUS DOLOMITE LUCAS DOLOMITE	TYPE A4, A3	
CONCRETE MATERIALS INC. QUARRY AT MANCHESTER, NY OFFICE AT BROCKPORT, NY	ONONDAGA FORMATION (LIMESTONE)	TYPE A4, A3	
WARREN BROS QUARRY AT CANOGA, NY OFFICE AT GENEVA, NY	ONONDAGA FORMATION (LIMESTONE)	TYPE A4, A3	
FRANCE STONE CO. (FORMERLY NORTHERN OHIO STONE CO.) QUARRY AT FLAT ROCK, OH OFFICE AT TOLEDO, OH	LUCAS DOLOMITE	TYPE A4, A3	

POSSIBLE SOURCES FOR TYPE A6, A4, A3, (ARMOR S

SE	RADIAL DISTANCE	LABORATORY TEST RECORD			D
		DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	
	132 M.	MAY 1971	ORD LAB LAB # 101/71.358C	LITTLE SODUS BAY, NY, PIER REPAIR (CONCRETE AGGREGATE)	UNKNOW
		FEBRUARY 1972	ORD LAB LAB # 103/72.607C	LITTLE SODUS BAY, NY, PIER REPAIR (CONCRETE AGGREGATE)	UNKNOW
		JUNE 1973	ORD LAB LAB # 103/73.630C	CONFINED DIKE DREDGE DISPOSAL PROGRAM (RIPRAP)	UNKNOW
		JANUARY 1974	ORD LAB LAB # 103/74.613C	LITTLE SODUS BAY, NY, PIER REPAIR (CONCRETE AGGREGATE)	UNKNOW
	171 M.	AUGUST 1967	ORD LAB LAB # 103/68.604C	PILOT STUDY CONFINED DIKE DISPOSAL PROGRAM CLEVELAND HARBOR (RIPRAP)	UNKNOWN
		APRIL 1972	ORD LAB LAB # 103/72.606C	WELLSVILLE REHABILITATION PROJECT, WELLSVILLE, NY, (DERRICK STONE)	UNKNOWN
		SEPTEMBER 1974	ORD LAB	CONFINED DREDGE SPOIL DISPOSAL AREA NO. 7, LORAIN HARBOR, OH	
	191 M.	DECEMBER 1968	ORD LAB LAB # 103/69.607C	CLEVELAND DIKED DISPOSAL AREA NO.2 CLEVELAND HARBOR, OH (CORE STONE AND ARMOR STONE)	1969
		MARCH 1972	ORD LAB LAB # 103/72.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (CORE, INTERMEDIATE, FILTER AND ARMOR STONE)	1973-19
	211 M.	MARCH 1972	ORD LAB LAB # 103/72.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (COARSE AGGREGATE FOR CONCRETE AND RIPRAP)	UNKNOWN
	95 M.	AUGUST 1973	ORD LAB LAB # 103/73.630C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (RIPRAP)	UNKNOWN
	122 M.	OCTOBER 1968	ORD LAB LAB # 103/74.601C	GREAT SODUS HARBOR, NY, EMER[illegible] WEST PIER REPAIR (BREAKWATER [illegible]	[illegible]
	204 M.	MARCH 1972	ORD LAB LAB # 103/72.[illegible]	CONFINED [illegible] PRO[illegible]	[illegible]

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CATTARAUGUS CREEK HARBOR, NEW YORK GENERAL DESIGN MEMORANDUM. P--ETC(U)
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UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	UNIT WEIGHT A RECORD. IT HA HOWEVER, IT WI
UNKNOWN	UNKNOWN	UNKNOWN	
			TESTING NOT C
1969	CLEVELAND DIKED DISPOSAL AREA NO2 CLEVELAND HARBOR, OH (ARMOR STONE)	SATISFACTORY	ALSO TESTED SPECIFIC GRA LEDGE ROCK V FACILITIES A
1973-1974	CLEVELAND DIKE EMERGENCY REPAIR (RIPRAP AND CORE STONE) AND CLEVELAND DIKE DISPOSAL AREA SITE 12	TOO EARLY TO EVALUATE	
UNKNOWN	UNKNOWN	UNKNOWN	SPECIFIC GRA RIPRAP MATER A VERY LOW U PROJECT. RA
UNKNOWN	UNKNOWN	UNKNOWN	UNIT WEIGHT P.C.F.
UNKNOWN	UNKNOWN	UNKNOWN	UNIT WEIGHT FROM 166 P.C 169 P.C.F.
UNKNOWN	UNKNOWN	UNKNOWN	UNIT WEIGHT FROM 153.5 171 P.C.F. LITIES NOT A

REMARKS
EIGHT AVERAGES ABOUT 139 P.C.F. THIS SAND HAS A GOOD SERVICE . IT HAS BEEN USED ON SEVERAL OUTER BREAKWALLS IN THIS DISTRICT. R, IT WILL FAIL MOST DURABILITY TESTS.
G NOT COMPLETE
ESTED FOR FINE AND COARSE AGGREGATES FOR CONCRETE AND CELL FILL. IC GRAVITY FOR FINE AGGREGATE IS 2.59, FOR COARSE AGGREGATE 2.62 ROCK VARIES FROM 2.62 TO 2.75. SELF UNLOADING VESSELS AND BARGE TIES AVAILABLE.
IC GRAVITY FOR CONCRETE AGGREGATE IS 2,58. UNIT WEIGHT FOR MATERIALS VARY FROM 154 P.C.F. TO 161 P.C.F. LEDGE NO. 5 HAS LOW UNIT WEIGHT (138.5 P.C.F.) AND IS NOT ACCEPTABLE FOR THIS T. RAIL FACILITIES AVAILABLE.
IGHT IS 167
IGHT VARIES 6 P.C.F. TO .F.
IGHT VARIES 3.5 P.C.F. TO .F. RAIL FACI- NOT AVAILABLE.

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

POSSIBLE SOURCES FOR TYPE A6, A4, A3 (ARMOR STO

SOURCE	ROCK TYPE	PROPOSED USE
FRANCE STONE CO. QUARRY AT MONROE, MICHIGAN OFFICE AT TOLEDO, OHIO	BASS ISLAND FORMATION (DOLOMITE LIMESTONE)	TYPE A6, A4, A3
FRANCE STONE CO. QUARRY AT BLOOMVILLE, OHIO OFFICE AT TOLEDO, OHIO	COLUMBUS FORMATION (LIMESTONE)	TYPE A6, A4, A3
SANDUSKY CRUSHED STONE CO. QUARRY AT PARKERTOWN, OH OFFICE AT PARKERTOWN, OH	LUCAS AND COLUMBUS DOLOMITE	TYPE A4, A3
U.S. GYPSUM CO., QUARRY AT GENOA, OHIO OFFICE AT WOODVILLE, OHIO GLENN GRAFFICE AND SON, INC.	NIAGARAN DOLOMITE	TYPE A6. A4, A3
CHARLES PFIZER, CO. QUARRY AT GIBSONBURG, OHIO OFFICE AT GIBSONBURG, OHIO	NIAGARAN DOLOMITE	TYPE A6, A4, A3
NATIONAL LIME AND CHEMICAL CO. QUARRY AT SPORE, OHIO OFFICE AT FINDLAY, OHIO	COLUMBUS FORMATION (DOLOMITE)	TYPE A6, A4, A3
WYANDOT DOLOMITE, INC. QUARRY AT CAREY, OH OFFICE AT CAREY, OH	NIAGARAN DOLOMITE	TYPE A6, A4, A3
BROUGH STONE CO. QUARRY AT WEST MILLGROVE, OHIO OFFICE AT TOLEDO, OHIO	NIAGARAN DOLOMITE	TYPE A4, A3
NATIONAL LIME AND STONE CO. QUARRY AT CAREY, OHIO OFFICE AT FINDLAY, OHIO	NIAGARAN DOLOMITE	TYPE A6, A4, A3
TRI COUNTY LIMESTONE CO. QUARRY AT MARSEILLES, OHIO OFFICE AT MARSEILLES AND KENTON, OHIO	TYMOCHTEE FORMATION (DOLOMITE)	TYPE A6, A4, A3
E. KRAEMER AND SON, INC. QUARRY AT CLAY CENTER, OHIO OFFICE AT CLAY CENTER, OHIO	NIAGARAN DOLOMITE	TYPE A6, A4, A3
WOODVILLE LIME AND CHEMICAL CO. QUARRY AT WOODVILLE, OH OFFICE AT WOODVILLE, OH	NIAGARAN DOLOMITE	TYPE A6, A4, A3
NATIONAL LIME AND STONE CO. QUARRY AT MARION, OHIO OFFICE AT FINDLAY, OHIO	COLUMBUS FORMATION (DOLOMITE)	TYPE A6, A4, A3

(ARMOR STONE)

USE	RADIAL DISTANCE	LABORATORY TEST RECORD			
		DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	
3	213 M.	JANUARY 1973	ORD LAB LAB # 103/73.612C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNK
3	215 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNK
	219 M.	MARCH 1972	ORD LAB LAB # 103/72.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (FINE, AND COARSE AGGREGATES FOR CONCRETE, CELL FILL AND RIPRAP)	197
3	220 M.	MARCH 1972	ORD LAB LAB # 103/72.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (RIPRAP, CELL FILL, FINE AND COARSE AGGREGATE FOR CONCRETE)	UNK
3	223 M.	MARCH 1972	ORD LAB LAB # 103/72.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (RIPRAP)	UNK
3	225 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (RIPRAP AND ARMOR STONE)	UNK
	229 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE AND RIPRAP)	UNKN
	233 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNKN
	235 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNKN
	252 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNKN
	220 M.	MARCH 1972	ORD LAB LAB # 103/72.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNKN
	222 M.	OCTOBER 1970	ORD LAB LAB # 101/71.312C	LOCAL FLOOD PROTECTION, SANDUSKY RIVER, FREMONT, OH	1970-
	240 M.	NOVEMBER 1972	ORD LAB LAB # 103/73.606C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	UNKN

	SERVICE RECORD			
TED	DATE USED	PROJECT	EVALUATION	
L	UNKNOWN	UNKNOWN	UNKNOWN	ONLY WEIGH SMALL
L	UNKNOWN	UNKNOWN	UNKNOWN	ONLY T FOR 3 VARIES
L RE- AND	1973-1974	SANDUSKY RIVER LOCAL FLOOD PROTECTION PROJECT, FREMONT, OH (RIPRAP)	TOO EARLY TO EVALUATE	CHERT STONE P.C.F. FOR CO
L PRO- AND)	UNKNOWN	UNKNOWN	UNKNOWN	ONLY T 168 P. TO G. CONSTR
L	UNKNOWN	UNKNOWN	UNKNOWN	UNIT W AVAILA
)	UNKNOWN	UNKNOWN	UNKNOWN	ONLY T DARY L RAIL F SIZES
P)	UNKNOWN	UNKNOWN	UNKNOWN	TWO LI TO 168. 171.6 F STANDAR
	UNKNOWN	UNKNOWN	UNKNOWN	UNIT WE AVAILAB
	UNKNOWN	UNKNOWN	UNKNOWN	ONLY TH 157 P.C PRODUCE GRADATI
	UNKNOWN	UNKNOWN	UNKNOWN	ONLY TH TO 168
	UNKNOWN	UNKNOWN	UNKNOWN	UNIT WE 157 P.C RAIL FA AVAILAB
Y	1970-1972	LOCAL FLOOD PROTECTION SANDUSKY RIVER, FREMONT, OH	SATISFACTORY	SPECIFI 2.68. AVAILAB
	UNKNOWN	UNKNOWN	UNKNOWN	UNIT WE 161 P.C RAIL FA AVAILAB

REMARKS
ONLY THE MASSIVE ZONE IN LIFT ONE ACCEPTABLE FOR ARMOR STONE. UNIT WEIGHT VARIES FROM 163 P.C.F. TO 170 P.C.F. OTHER BEDS ACCEPTABLE FOR SMALLER SIZE STONE. RAIL FACILITIES AVAILABLE.
ONLY THE MASSIVE BED (6.0 FT. THICK) IN THE THIRD LIFT IS ACCEPTABLE FOR 3 TON STONE. OTHER BEDS ACCEPTABLE FOR SMALLER SIZES: UNIT WEIGHT VARIES FROM 156 P.C.F. TO 163 P.C.F. RAIL FACILITIES AVAILABLE.
CHERT ZONES IN LIFTS 2 AND 3 ARE NOT ACCEPTABLE FOR THESE PRODUCTS. STONE FROM LIFTS 1 AND 4 ACCEPTABLE. UNIT WEIGHT VARIES FROM 162.2 P.C.F. TO 169.7 P.C.F. SPECIFIC GRAVITY FOR FINE AGGREGATES IS 2.62; FOR COARSE AGGREGATE 2.65; FOR RIPRAP 2.69; RAIL FACILITIES AVAILABLE.
ONLY THE FIRST LIFT ACCEPTABLE. UNIT WEIGHT VARIES FROM 158 P.C.F. TO 168 P.C.F. RAIL FACILITIES AVAILABLE. U.S. GYPSUM LEASES THE QUARRY TO G. GRAFFICE AND SONS, INC. WOODVILLE, OH, FOR THE PRODUCTION OF CONSTRUCTION MATERIALS.
UNIT WEIGHT VARIES FROM 153 P.C.F. TO 159 P.C.F. RAIL FACILITIES AVAILABLE.
ONLY THE BASAL 15.0 FT. IN THE QUARRY IS CAPABLE OF PRODUCING SECONDARY LAYER STONE. THE UNIT WEIGHT VARIES FROM 163 P.C.F. TO 165 P.C.F. RAIL FACILITIES AVAILABLE. NOTE: MANAGEMENT RELUCTANT TO PRODUCE SIZES LARGER THAN OHIO DEPARTMENT OF HIGHWAYS STANDARD GRADATION.
TWO LIFTS TESTED. UNIT WEIGHT OF UPPER LIFT VARIES FROM 157.8 P.C.F. TO 168.4 P.C.F. UNIT WEIGHT OF LOWER LIFT VARIES FROM 170.3 P.C.F. TO 171.6 P.C.F. RAIL FACILITIES AVAILABLE. MANAGEMENT WILL PROVIDE ONLY STANDARD CRUSHED MATERIALS.
UNIT WEIGHT VARIES FROM 158 P.C.F. TO 166 P.C.F. RAIL FACILITIES AVAILABLE SEVERAL MILES AWAY FROM QUARRY.
ONLY THE NIAGARAN DOLOMITE ACCEPTABLE. UNIT WEIGHT VARIES FROM 142 TO 157 P.C.F. RAIL FACILITIES AVAILABLE. NOTE: MANAGEMENT RELUCTANT TO PRODUCE SIZES LARGER THAN OHIO DEPARTMENT OF HIGHWAYS STANDARD GRADATION.
ONLY THE FIRST LIFT IS ACCEPTABLE. UNIT WEIGHT VARIES FROM 152 P.C.F. TO 168 P.C.F. RAIL FACILITIES AVAILABLE SEVERAL MILES FROM QUARRY.
UNIT WEIGHT VARIES FROM 157 P.C.F. TO 169 P.C.F. RAIL FACILITIES AVAILABLE.
SPECIFIC GRAVITY IS 2.68. RAIL FACILITIES AVAILABLE.
UNIT WEIGHTS VARY FROM [illegible]1 P.C.F. TO 170 P.C.F. RAIL FACILITIES AVAILABLE

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

POSSIBLE SOURCES FOR FINE AGGREGATE FOR CONCRETE:

SOURCE	ROCK TYPE	PROPOSED USE	RA DIST
VALLEY SAND AND GFAVFL CORP. PIT AT SCOTTSVILLE, N. Y. OFFICE AT ROCHESTER, N. Y.	NATURAL SAND AND GRAVEL	FINE AGGREGATE F1 STONE	77
R. W. SIDLEY STOCKPILE AT ASHTABULA, OHIO OFFICE AT PAINESVILLE, OHIO	NATURAL SAND AND GRAVFL	FINE AGGREGATE F1 STONE	27

ETE: F1 (FILTER STONE)

RADIAL DISTANCE	LABORATORY TEST RECORD			
	DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	DATE
77 M.	JUNE 1971	NYS DOT LAB # 71AF35	UNKNOWN	UNKNOWN
27 M.		NOT TESTED	UNKNOWN	UNKNOWN

SERVICE RECORD

DATE USED	PROJECT	EVALUATION	
UNKNOWN	UNKNOWN	UNKNOWN	UNIT WEIGHT IS
UNKNOWN	UNKNOWN	UNKNOWN	UNIT WEIGHT IS

REMARKS
IGHT IS 162.[illegible] P.C.F. ONLY TRUCK HAUL AVAILABLE.
IGHT IS 155.3 P.C.F.: SELF UNLOADING BOATS AVAILABLE.

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

PLATE C12

POSSIBLE SOURCES FOR TYPE A6, A4, A3. (ARMOR S

SOURCE	ROCK TYPE	PROPOSED USE
INDIANA LIMESTONE CO. QUARRY NEAR BEDFORD, INDIANA OFFICE AT BEDFORD, INDIANA	SALEM FORMATION	TYPE A6 & A4

(ARMOR STONE)

USE	RADIAL DISTANCE	LABORATORY TEST RECORD			
		DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	
	452 M.	JANUARY 1973	ORD LAB LAB # 103/73.612C	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (ARMOR STONE)	JULY

...TED	SERVICE RECORD		
	DATE USED	PROJECT	EVALUATION
	JULY 1972	CLEVELAND HARBOR, OUTER BREAKWATER REPAIR	TOO EARLY TO EVALUATE

REMARKS
UNIT WEIGHTS VARY FROM 118 P.C.F. TO 155 P.C.F. RAIL FACILITIES AVAILABLE.

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

POSSIBLE SOURCES FOR A1 (ARMOR STONE); B6, B4, B3 (UNDERLAYER STONE); C1 (CORE STONE); B.

SOURCE	ROCK TYPE	PROPOSED USE	RA DIS
HOUDAILLE CONSTRUCTION MATERIALS, INC. QUARRY AT CLARENCE, N. Y. OFFICE AT CLARENCE, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	
NIAGARA STONE DIV. OF GREAT LAKES COLOR PRINTING CORP., QUARRY AT NIAGARA FALLS, N. Y. (PLETCHERS CORNERS) OFFICE AT NIAGARA FALLS, N. Y.	LOCKPORT FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	[illegible]
LANCASTER STONE PRODUCTS CORP. QUARRY AT CLARENCE, N. Y. OFFICE AT WILLIAMSVILLE, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	[illegible]
FRONTIER STONE PRODUCTS, INC. QUARRY AT LOCKPORT, N. Y. OFFICE AT LOCKPORT, N. Y.	LOCKPORT FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	5
ROYALTON STONE PRODUCTS, INC. QUARRY AT GASPORT, N. Y. OFFICE AT GASPORT, N. Y.	LOCKPORT FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	5
FEDERAL CRUSHED STONE DIV. OF BUFFALO SLAG CO. INC., QUARRY AT CHEEKTOWAGA N. Y., OFFICE AT BUFFALO, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	3
LANCASTER STONE PRODUCTS, INC. QUARRY AT TOWN OF ALABAMA OFFICE AT WILLIAMSVILLE, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B 4, B3, C1, B.1, R.1, F2	
COUNTY LINE STONE CO. INC. QUARRY AT AKRON, N. Y. OFFICE AT AKRON, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	4

E); B.1, R.5 (RIPRAP); F2 (FILTER STONE)

RADIAL DISTANCE	LABORATORY TEST RECORD			DAT
	DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	
42 M.	JULY 1959	ORD LAB LAB # 412/59Z	NORTH ENTRANCE, BUFFALO HARBOR, N. Y. (CORE STONE)	UNKNOWN
	SEPTEMBER 1965	ORD LAB LAB # 103/66.602C	LOCAL FLOOD PROTECTION PROJECT, SMOKES CREEK, STAGE 11, (RIPRAP)	UNKNOWN
	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP AND SPALLS)	1971
43 M.	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	UNKNOWN
46 M.	OCTOBER 1967	ORD LAB LAB # 103/68.605C	BUFFALO DIKED DISPOSAL AREA #1 (RIPRAP)	UNKNOWN
50 M.	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	UNKNOWN
	AUGUST 1974	UNKNOWN	CONFINED DIKE DISPOSAL PROGRAM, BUFFALO HARBOR, N. Y., SITE 4 (ARMOR STONE)	UNKNOWN
55 M.	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	UNKNOWN
37 M	NOVEMBER 1965	ORD LAB LAB # 103/66.605C	LOCAL FLOOD PROTECTION PROJECT, SMOKES CREEK, STAGE 11 (RIPRAP)	UNKNOWN
	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	UNKNOWN
	SEPTEMBER 1974	ORD LAB	CONFINED DREDGE SPOIL DISPOSAL AREAS	
48 M.	MAY 1967	ORD LAB LAB # 103/67.605C	WARSAW, N.Y. FLOOD CONTROL PROJECT (RIPRAP)	1967
	FEBRUARY 1971	ORD LAB LAB # 103/71.612C	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	1971

SERVICE RECORD

DATE USED	PROJECT	EVALUATION	
OWN	UNKNOWN	UNKNOWN	
OWN	UNKNOWN	TOO THIN BEDDED FOR USE ON PROJECT TESTED FOR	
1	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP AND SPALLS)	TOO EARLY TO EVALUATE	ONLY THE SECOND LI 165 P.C.F. TO 171
OWN	UNKNOWN	UNKNOWN	BOTH LIFTS CONSIST MEMBERS ACCEPTABL RAIL FACILITIES A LARGE SIZE MATERIA
OWN	UNKNOWN	UNKNOWN	ONLY THE LOWER LIF TO 169 P.C.F. RAI
OWN	UNKNOWN	UNKNOWN	THE DECEW MEMBER FROM 162 P.C.F.
OWN	UNKNOWN	UNKNOWN	CURRENTLY THE GASP STONE. LOADING FA
OWN	UNKNOWN	UNKNOWN	ONLY MATERIALS FRO FROM 163 P.C.F. TO
OWN	UNKNOWN	UNKNOWN	UNIT WEIGHT AVERAG
OWN	UNKNOWN	UNKNOWN	ONLY THE FIRST LIF 166 P.C.F. TO 169
			QUARRY OPENED DURI SUMMER OF 1974. MA ERIALS,RIPRAP&AGGR GATES CURRENTLY AR BEING TESTED BY OR
	WARSAW, N.Y., FLOOD CONTROL PROJECT (RIPRAP)	APPEARS SATISFACTORY	THE SECOND LIFT O APPROVED FOR RIPRA IS FROM THE MOORE MEMBER OF THE ONO FORMATION.
	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	TOO EARLY TO EVALUATE	ONLY THE SECOND L EAST FACE TESTED THIS PROJECT. UNI WEIGHT AVERAGES 1 P.C.F. RAIL FACIL NOT AVAILABLE

REMARKS
COND LIFT TESTED AND USED. UNIT WEIGHT VARIES FROM TO 171 P.C.F. RAIL FACILITIES ARE AVAILABLE.
CONSISTING OF OAK ORCHARD, ERAMOSA AND UPPER GOAT ISLAND EPTABLE. UNIT WEIGHT VARIES FROM 166 P.C.F. TO 174 P.C.F. TIES AVAILABLE. MANAGEMENT MAY BE RELUCTANT TO PRODUCE MATERIAL.
WER LIFT TESTED (1967). UNIT WEIGHT VARIES FROM 166 P.C.F. .F. RAIL FACILITIES NOT AVAILABLE.
EMBER NOT ACCEPTABLE FOR THIS PROJECT. UNIT WEIGHTS VARY .C.F. RAIL FACILITIES NOT AVAILABLE.
HE GASPORT MEMBER IS BEING TESTED FOR 10 TO 20 TON ARMOR DING FACILITIES ON NYS BARGE CANAL TO BE AVAILABLF
ALS FROM EAST END OF QUARRY TESTED. UNIT WEIGHT VARIES C.F. TO 165 P.C.F. RAIL FACILITIES AVAILABLE.
AVERAGES 168 P.C.F.
RST LIFT, WEST QUARRY TESTED. UNIT WEIGHT VARIES FROM TO 169 P.C.F. RAIL FACILITIES NOT AVAILABLE.
D DURING 974. MAT- P&AGGRE- TLY ARE BY ORDL.
IFT ONLY I RIPRAP AN MOOREHOUSE ONONDAGA
OND LIFT, STED FOR UNIT ES 168 ACILITIES

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

PLATE C14

POSSIBLE SOURCES FOR A1 (ARMOR STONE); B6; B4, B3 (UNDERLAYER STONE); C1 (CORE STONE); B.1,

SOURCE	ROCK TYPE	PROPOSED USE	RAD DISTA
GENESEE STONE PRODUCTS CORP. QUARRY AT STAFFORD, N. Y. OFFICE AT BATAVIA, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	64
CONCRETE MATERIALS, INC. QUARRY AT SWEDEN, N. Y. OFFICE AT SWEDEN, N. Y.	LOCKPORT DOLOMITE	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	77
GENERAL CRUSHED STONE CO. QUARRY AT HONEOYE FALLS, N. Y. OFFICE AT EASTON, PA.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	80
DOLOMITE PRODUCTS QUARRY AT GATES CENTER, N. Y. OFFICE AT ROCHESTER, N. Y.	LOCKPORT FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	82
DOLOMITE PRODUCTS QUARRY AT PENFIELD, N. Y. OFFICE AT PENFIELD, N. Y.	LOCKPORT FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	92
CAYUGA CRUSHED STONE CO., INC. QUARRY AT SOUTH LANSING, N. Y. OFFICE AT SOUTH LANSING, N. Y.	TULLY FORMATION (LIMESTONE)	TYPE C1, F2, D1	133
STANDARD SLAG CO. QUARRY AT MARBLEHEAD, OHIO OFFICE AT MARBLEHEAD, OHIO	LUCAS FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	191
CONCRETE MATERIALS INC. QUARRY AT MANCHESTER, N. Y. OFFICE AT BROCKPORT, N. Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	95
WARREN BROS. QUARRY AT CANOGA, N. Y. OFFICE AT GENEVA, N.Y.	ONONDAGA FORMATION (LIMESTONE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	122
GENERAL CRUSHED STONE INC. QUARRY AT SODUS, N. Y. OFFICE AT EASTON, PA.	LOCKPORT FORMATION (DOLOMITE)	TYPE A1, B6, B4, B3, C1, B.1, R.5, F2	132

64 M	DECEMBER 1971	ORD LAB LAB # 103/72.6020	WELLSVILLE RECTIFICATION PROJECT, WELLSVILLE, N. Y. (RIPRAP)	UNKNOWN
77 M	JANUARY 1971	ORD LAB LAB # 101/71.3620	ROCHESTER HARBOR, N. Y. EAST PIER REPAIRS	1971
80 M.	DECEMBER 1971	ORD LAB LAB # 103/72.6020	WELLSVILLE RECTIFICATION PROJECT, WELLSVILLE, N. Y. (RIPRAP)	1971
82 M	MAY 1972	ORD LAB LAB # 103/72.6100	OAK ORCHARD HARBOR, N. Y. (CORE STONE, COVER STONE AND CONCRETE AGGREGATE)	UNKNOWN
[illegible]2 M	UNKNOWN	UNKNOWN	BUFFALO DIKED DISPOSAL AREA #2 (RIPRAP)	UNKNOWN
	JUNE 1973	ORD LAB LAB # 103/73.6030	CONFINED DREDGE SPOIL DISPOSAL PROGRAM	UNKNOWN
133 M.	SEPTEMBER 1965	ORD LAB LAB # 103/66.6000	CAYUGA INLET, STAGES I AND II	1965, 1967 AN
191 M.	DECEMBER 1968	ORD LAB LAB # 103/69.6070	CLEVELAND DIKED DISPOSAL AREA # 2 CLEVELAND HARBOR, OH. (CORE STONE AND ARMOR STONE)	1969
	MARCH 1972	ORD LAB LAB # 103/72.6060	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (CORE, INTERMEDIATE, FILTER AND ARMOR STONE)	1973-1974
95 M	AUGUST 1973	ORD LAB LAB # 103/73.6300	CONFINED DREDGE SPOIL DISPOSAL PROGRAM (RIPRAP)	UNKNOWN
122 M	OCTOBER 1968	ORD LAB LAB # 103/74.6010	GREAT SODUS HARBOR, N.Y. EMERGENCY WEST PIER REPAIR (BREAKWATER STONE)	UNKNOWN
132 M	MAY 1971	ORD LAB LAB # 101/71.3580	LITTLE SODUS BAY, N. Y. PIER REPAIR (CONCRETE AGGREGATE)	UNKNOWN

SERVICE RECORD			
DATE USED	PROJECT	EVALUATION	
OWN	UNKNOWN	UNKNOWN	ONLY THE FIRST AND 168 P.C.F. RAIL F
	ROCHESTER HARBOR, N. Y. EAST PIER REPAIRS	SATISFACTORY	SPECIFIC GRAVITY IS
	WELLSVILLE EMERGENCY FLOOD CONTROL PROJECT (RIPRAP)	SATISFACTORY	QUARRY NOT RESPONSI 166 P.C.F. TO 168
OWN	UNKNOWN	UNKNOWN	ONLY THE FIRST LIF UNIT WEIGHT IS APP AT QUARRY.
OWN	UNKNOWN	UNKNOWN	ONLY THE PENFIELD NOT AVAILABLE.
OWN	UNKNOWN	UNKNOWN	UNIT WEIGHT VARIES
, 1967 AND 1968	CAYUGA INLET, STAGES I, II AND III	SATISFACTORY	UNIT WEIGHT AVERAG
	CLEVELAND DIKED DISPOSAL AREA # 2 CLEVELAND HARBOR, OH (ARMOR STONE)	SATISFACTORY	
-1974	CLEVELAND DIKE EMERGENCY REPAIR (RIPRAP AND CORE STONE) AND CLEVELAND DIKE DISPOSAL AREA SITE 12	TOO EARLY TO EVALUATE	ALSO TESTED FOR CELL FILL, SPECIF COARSE AGGREGATE UNLOADING VESSELS
OWN	UNKNOWN	UNKNOWN	UNIT WEIGHT IS 167
OWN	UNKNOWN	UNKNOWN	UNIT WEIGHT VARIES 166 P.C.F. TO 169
OWN	UNKNOWN	UNKNOWN	

REMARKS
RST AND SECOND LIFT ACCEPTABLE. UNIT WEIGHT AVERAGES RAIL FACILITIES NOT AVAILABLE.
AVITY IS 2.75.
RESPONSIBLE FOR GRADATION, UNIT WEIGHT VARIES FROM TO 168 P.C.F. RAIL FACILITIES NOT AVAILABLE.
RST LIFT (PENFIELD MEMBER) ACCEPTABLE FOR THIS PROJECT. T IS APPROXIMATELY 171 P.C.F. RAIL FACILITIES AVAILABLE
NFIELD MEMBER ACCEPTABLE FOR THIS PROJECT. RAIL FACILITIES BLE.
T VARIES FROM 163 P.C.F. TO 171 P.C.F.
T AVERAGES 171.2 P.C.F. RAIL FACILITIES AVAILABLE.
TED FOR FINE AND COARSE AGGREGATES FOR CONCRETE AND , SPECIFIC GRAVITY FOR FINE AGGREGATE IS 2.59; FOR GREGATE 2.62 LEDGE ROCK VARIES FROM 2.62 TO 2.75. SELF VESSELS AND BARGE FACILITIES AVAILABLE.
T IS 167 P.C.F.
T VARIES FROM TO 169 P.C.F

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

POSSIBLE SOURCES FOR FINE AGGREGATE FOR CONCRETE; F

SOURCE	ROCK TYPE	PROPOSED USE	RA DIS
PINE HILL CONCRETE MIX CO. PIT AT LANCASTER, N. Y. OFFICE AT BUFFALO, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	32
PINE HILLS CONCRETE MIX CO. PITS AT NEWSTEAD, N. Y. OFFICE AT BUFFALO, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	50
DAN GERNATT GRAVEL PROD. PIT AT COLLINS, N. Y. OFFICE AT COLLINS, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	12
HANOVER SAND AND GRAVEL, INC. PIT AT HANOVER, N. Y. OFFICE AT SILVER CREEK, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	5
COUNTRY SIDE SAND AND GRAVEL PIT AT DAYTON, N. Y. OFFICE AT COLLINS, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	13
SPENCER AND HALEY, INC. PIT AT FREEDOM, N. Y. OFFICE AT DELEVAN, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	43
BUFFALO SLAG CO. PIT AT MACHIAS, N. Y. STOCKPILE AT LACKAWANNA, N. Y. OFFICE AT BUFFALO, N. Y.	NATURAL SAND	FINE AGGREGATE F1 STONE	35
EASTERN ROCK PRODUCTS PIT AT BOONEVILLE, N. Y. OFFICE AT UTICA, N. Y.	GLACIAL DEPOSIT	FINE AGGREGATE F1 STONE	20
BUFFALO SLAG CO. PIT AT ALFRED STATION, N. Y. OFFICE AT BUFFALO, N. Y.	GLACIAL DEPOSIT	FINE AGGREGATE F1 STONE	79
ABRAM CLEASON PIT AT PALMYRA, N. Y. OFFICE AT NEWARK, N. Y.	GLACIAL DEPOSIT	F1 STONE	103
R. R. DEWITT PIT # 5, AT RIDGEWAY, N. Y. OFFICE AT PAVILION, N. Y.	BEACH DEPOSIT	FINE AGGREGATE F1 STONE	73
ERIE SAND AND GRAVEL CO. STOCKPILE AT LACKAWANNA, N. Y. OFFICE AT ERIE, PA.	LAKE SAND	FINE AGGREGATE F1 STONE	25

[illegible]

USE	RADIAL DISTANCE	LABORATORY TEST RECORD DATE TESTED	LABORATORY	PROJECT FOR WHICH TESTED	
	[illegible] M	FEBRUARY 1971	NYS DOT LAB # [illegible]	UNKNOWN	UNKN
	[illegible] M	MARCH 1971 MARCH 1971	NYS DOT LAB # [illegible] NYS DOT LAB # [illegible]	UNKNOWN	UNKN
	[illegible] M	FEBRUARY 1971	NYS DOT LAB # [illegible]	UNKNOWN	UNKN
	[illegible] M	JANUARY 1971	NYS DOT LAB # [illegible]	UNKNOWN	UNKN
	[illegible] M	FEBRUARY 1971	NYS DOT LAB # [illegible]	UNKNOWN	UNKN
	[illegible] M	JANUARY [illegible]	NYS DOT LAB # [illegible]	UNKNOWN	UNKN
	[illegible] M	FEBRUARY [illegible]	ORD LAB LAB # [illegible]	BLACK ROCK LOCK REHABILITATION	MAY 1
	[illegible] M	MAY [illegible]	ORD LAB LAB # [illegible]	LITTLE SODUS BAY HARBOR, N. Y. PIER REHABILITATION	1973
	[illegible] M	JANUARY [illegible] APRIL [illegible]	NYS DOT LAB # 69AF233 ORD LAB LAB # UNKNOWN	UNKNOWN WELLSVILLE REHABILITATION PROJECT N. Y.	UNKNO 1974
	[illegible] M	MARCH 1971	NYS DOT LAB # 70AF1[illegible]2	UNKNOWN	UNKNO
	[illegible] M	DECEMBER [illegible]	ORD LAB LAB # 103/72.61[illegible]	ROCHESTER HARBOR, N. Y. EAST PIER REPAIR	1973
	[illegible] M	JANUARY 1971	NYS DOT LAB # 70AF154	UNKNOWN	UNKNO

SERVICE RECORD			
DATE USED	PROJECT	EVALUATION	
UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	
UNKNOWN	UNKNOWN	UNKNOWN	
MAY 1973	BLACK ROCK LOCK REHABILITATION	TOO EARLY TO EVALUATE	LOW ALKALI
1973	LITTLE SODUS BAY HARBOR, N. Y. PIER REHABILITATION	TOO EARLY TO EVALUATE	SPECIFIC GR
UNKNOWN 1974	UNKNOWN WELLSVILLE REHABILITATION PROJECT N. Y. (CONCRETE WEIR)	UNKNOWN TOO EARLY TO EVALUATE	SPECIFIC GR
UNKNOWN	UNKNOWN	UNKNOWN	SPECIFIC GR
1973	ROCHESTER HARBOR, N. Y. EAST PIER REPAIR	SATISFACTORY	SPECIFIC GR IS 2.58
UNKNOWN	UNKNOWN	UNKNOWN	SPECIFIC GR IS 2.57

REMARKS
ALKALI CEMENT REQUIRED.
IFIC GRAVITY IS 2.62.
IFIC GRAVITY IS 2.5[illegible].
IFIC GRAVITY IS 2.58.

IFIC GRAVITY .58	
IFIC GRAVITY .57	

CATTARAUGUS HARBOR, NEW YORK

MATERIAL SOURCES

MATERIAL SURVEY

U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO
FRONTIER STONE PRODUCTS QUARRY AT LOCKPORT, N.Y.	LOCKPORT DOLOMITE		ORD 103/75.60[illegible]

SUMMARY SHEET FOR LABORATOR

LAB. NO.	TEST RESU					
	PETROGRAPHIC ANALYSIS	SP.GRAV.	ABS.	$MgSO_4$	L.A.A.	F&
6.6048	(FG-1-1) DOLOMITE - MODERATELY HARD, MASSIVE, FINE-GRAINED, DENSE TO SLIGHTLY POROUS, MANY STYLOLITES SPACED 1/2" APART - MANY ARE DISCONTINUOUS AND TIGHT EVEN AFTER FREEZE-THAW AND WET-DRY TESTING, BLOCKY FRACTURE, LIGHT MEDIUM GRAY WITH A SLIGHT AMOUNT OF MEDIUM GRAY MOTTLING.	2.74	1.68%			
	(FG-1-2)	2.75	1.52%			
	(FG-1-3) DOLOMITE - SAME AS FG-1-1, BUT STYLOLITES ARE NOT AS COMMON AND ARE SPACED AT LEAST 5 INCHES APART, GYPSUM FILLED VUGS ARE MORE COMMON AND LARGER (UP TO 3/4 INCH DIAMETER).	2.73	1.31%			
	(FG-1-4)	2.74	0.95%			
	(FG-2-1)	2.69	1.51%			
	(FG-2-2) DOLOMITE - MODERATELY HARD, MASSIVE, FINE-GRAINED, DENSE BUT WITH SCATTERED MACROPORES AND SMALL, LINED VUGS; SUB-BLOCKY FRACTURE, PALE YELLOWISH BROWN GRAY	2.65	1.45%			
	(FG-3-1) DOLOMITE - MODERATELY HARD, MASSIVE, FINE-GRAINED BUT CONTAINS COARSE CALCITIC FOSSIL FRAGMENTS, DENSE BUT WITH NUMEROUS MACROPORES AND SEVERAL SMALL LINED VUGS PARTLY FILLED WITH GYPSUM, YELLOWISH GRAY WITH MEDIUM GRAY MOTTLING.	2.68	1.66%			
	(FG-3-2)	2.68	1.25%			
	(FG-3-3)	2.69	1.38%			
	(FG-3-4)	2.67	1.35%			

TORY TESTING

RESULTS

A.	F&E PART	L.W. PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
						SURFACE SPALLING AND SOME PARTING OF THE STYLOLITIC SEAMS. SAME AS FG-1-1 ABOVE.	ALL MA BER OF TO 20
					NO EFFECT NO EFFECT		THE AV
					NO EFFECT	NO EFFECT EXCEPT FOR VERY MINOR AMOUNT OF SURFACE SPALLING. NO EFFECT EXCEPT FOR A VERY MINOR AMOUNT OF SURFACE SPALLING.	THE AV THE AV
					NO EFFECT	NO EFFECT EXCEPT FOR A VERY MINOR AMOUNT OF SURFACE SPALLING.	
					NO EFFECT.		

S)	REMARKS
ING	ALL MATERIAL IN ORDL #103/75.604B IS FROM THE GASPORT MEMBER OF THE LOCKPORT DOLOMITE. ALL STONE WAS TESTED FOR 10 TO 20 TON ARMOR STONE FOR BUFFALO HARBOR, N.Y. SITE 4.
R	THE AVERAGE UNIT WEIGHT FOR FG-1 IS 171 P.C.F.
-	THE AVERAGE UNIT WEIGHT FOR FG-2 IS 167 P.C.F. THE AVERAGE UNIT WEIGHT FOR FG-3 IS 167 P.C.F.
NOR	

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO
FEDERAL CRUSHED STONE, DIV. OF BUFFALO SLAG CO. QUARRY AT CHEEKTOWAGA, N.Y. OFFICE AT BUFFALO, N.Y.	ONONDAGA LIMESTONE		ORD 103/66.605C
LANCASTER STONE PRODUCTS CORP. QUARRY NEAR BASOM, TOWN OF ALABAMA, N.Y. OFFICE AT WILLIAMSVILLE, N.Y.	ONONDAGA LIMESTONE		ORD 103/75.615B
			ORD 103/75B615B

SUMMARY SHEET FOR LABORATO

LAB. NO.	TEST RE					
	PETROGRAPHIC ANALYSIS	SP. GRAV.	ABS	$MgSO_4$	L.A.A.	F
D 3/66.605C	LIMESTONE AND DOLOMITIC LIMESTONE - LIMESTONE IS HARD, FINELY-CRYSTALLINE TO LITHOGRAPHIC, NON FOSSILFEROUS AND IS MIXED WITH DOLOMITIC LIMESTONE THAT IS HARD, MEDIUM-GRAINED, FOSSILFEROUS. ROCK CONTAINS ABUNDANT CHERT THAT IS DENSE, NON-FRACTURED AND NON-POROUS. TIGHT STYLOLITES ARE PRESENT. GENERALLY THE ROCK IS VERY HARD AND HAS AN IRREGULAR TO SEMICONCHOIDAL FRACTURE; ~~DUSKY YELLOWISH BROWN TO DARK YELLOWISH BROWN.~~	2.69	0.3%			
D 3/75.615B	DOLOMITIC LIMESTONE - 8 TO 15%; LIMESTONE - TRACE, CHERTY ARGILLACEOUS LIMESTONE - 2 TO 7%, CHERTY ARGILLACEOUS LIMESTONE - 10-20%, CHERTY ARGILLACEOUS LIMESTONE - 28 TO 43%, CHERTY ARGILLACEOUS LIMESTONE 21 TO 41%.	2.59 2.61 2.63	1.43% 1.23% 0.86%	5.9% 0.3%	36.2% 37.5%	
D 3/7586158	(LA-1) LIMESTONE - SOFT, CRUMBLES EASILY, FINE-GRAINED, ARGILLACEOUS AND CHERTY. CHERT EXCEEDS 50% OF THE ROLL AS NODULES AND SEAMS, HARD, DENSE. ROCK SPLITS AND FRACTURES ALONG AND THROUGH BEDDING PLANES, IRON STAINING, DARK YELLOWISH BROWN.					
	(LA-2) LIMESTONE - ~~(CHERTY ARGILLACEOUS LIMESTONE) AS ABOVE BUT WITH LESS~~ IRON STAINING. (LA-3) LIMESTONE (CHERTY ARGILLACEOUS LIMESTONE) AS ABOVE, BUT CHERT IS DARKER IN COLOR, LIGHT TO MEDIUM GRAY.					
	(LA-4) LIMESTONE - (CHERTY ARGILLACEOUS LIMESTONE) AS ABOVE, BUT DARKER COLOR. THE LIMESTONE IS BROWNISH BLACK, THE CHERT IS MEDIUM TO DARK GRAY. THE LIMESTONE CONTAINS SOME SLICKENSIDES. (LA-5) LIMESTONE (CHERTY ARGILLACEOUS LIMESTONE) AS ABOVE.					
	(LA-6) LIMESTONE (CHERTY ARGILLACEOUS LIMESTONE) THE LIMESTONE IS HARDER AND DENSER. THE ROCK SPLITS AND FRACTURES BUT LESS READILY THAN IN LA-1 THROUGH LA-5. THE LIMESTONE IS BROWNISH BLACK, THE CHERT MEDIUM TO DARK GRAY. CHERT MAKES UP LESS THAN 50% OF THE ROCK.					

ATORY TESTING

RESULTS

.A.A	F&E PART	L.W. PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
					NO SIGNIFICANT EFFECT	NO SIGNIFICANT EFFECT	TE RI
36.2% 37.5%	2% 2% 1%						S A (A U
					NO EFFECT	SURFACE SPALLING. NUMEROUS FRACTURES DEVELOPED.	T E G
					NO EFFECT NO EFFECT	SURFACE SPALLING, SEVERAL FRACTURES DEVELOPED. SURFACE SPALLING TO ALMOST DISINTERAGATION. NUMEROUS FRACTURES DEVELOPED.	
					NO EFFECT NO EFFECT	SOME SURFACE SPALLING SOME SURFACE SPALLING AND CRACK DEVELOPMENT.	
					NO EFFECT		

YCLES)	REMARKS
	TESTED FOR SMOKES CREEK FLOOD PROTECTION PROJECT, STAGE III RIPRAP.
	SOURCE SAMPLED AND TESTED FOR CONCRETE AGGREGATES. QUESTIONABLE QUALITY FOR USE AS COARSE AGGREGATES FOR CONCRETE. (2.59-1/4-3/8 IN. 2.61-1/2-3/4-IN, 2.63-3/4-1".) MAY BE ACCEPTABLE FOR USE AS CELL FILL. EVALUATE CAREFULLY FOR OTHER USES.
US FRAC-	THIS BED IS OF QUESTIONABLE QUALITY. USE OF STONE FROM THE EXPOSED 6 BEDS NOT RECOMMENDED FOR ANY ROCK PRODUCT. SPECIFIC GRAVITY FOR THE LEDGE ROCK BEDS NOT PERFORMED BY ORDL.
L FRAC-	
ST DIS- FRACTURES	
D CRACK	

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO.
EASTERN ROCK PRODUCTS PIT AT BOONEVILLE, N.Y.	GLACIAL DEPOSITION		ORD 103/74.613C
			ORD 101/71.358C
FEDERAL CRUSHED STONE DIVISION OF BUFFALO SLAG QUARRY AT CHEEKTOWAGA, N.Y.	ONONDAGA LIMESTONE		ORD 103/72.606C
			ORD 103/72.612C
			ORD 101/73.337C
FRONTIER STONE PRODUCTS QUARRY AT LOCKPORT, N.Y.	LOCKPORT DOLOMITE		ORD 103/71.612C
ERIE SAND AND GRAVEL CO. STOCKPILE AT LACKAWANNA, N.Y.	LAKE SAND		NYS DOT 70AF154
			ORD 103/72.606C

SUMMARY SHEET FOR LABORATORY

TEST RESULTS					
PETROGRAPHIC ANALYSIS	SP. GRAV.	ABS.	$MgSO_4$	L.A.A.	F&E PA
QUARTZ - 60%, LIMESTONE AND DOLOMITE - 6%, SANDSTONE AND SILTSTONE - 3%, IGNEOUS AND METAMORPHIC - 29%, CHERT (POTENTIALLY REACTIVE) - 1%, WEATHERED ROCK FRAG. - TRACE, SHALE - 1%.					
QUARTZ - 46%, LIMESTONE AND DOLOMITE - 9%, SANDSTONE AND SILTSTONE -5%, IGNEOUS AND METAMORPHIC - 39%, CHERT (POTENTIALLY REACTIVE) - TRACE, WEATHERED ROCK FRAG. - TRACE, SHALE - 1%.	2.62	0.55%	8%		
ARGILLACEOUS DOLOMITIC LIMESTONE - 56%, HIGHLY ARG. DOLOMITIC LIMESTONE - 6%, LIMESTONE - 9%, CHERTY LIMESTONE - 28%.	NYS#1-2.69 NYS#2-2.68 NYS#3-2.70	0.51% 0.56% 0.22%	1%	17%	17% 9% 14%
(FC-1) LIMESTONE - HARD, FINE-GRAINED AND EVEN-TEXTURD TO MEDIUM-GRAINED DENSE, POTENTIAL WEAK BEDDING PLANES, SUB CONCHOIDAL AND FRACTURE, DUSKY YELLOWISH BROWN.	2.71	0.14%			
(FC-1L) LIMESTONE - HARD, FINE-GRAINED, EVEN-TEXTURED, CHERTY, DENSE, SUB-CONCHOIDAL TO BLOCKY FRACTURE, DUSKY YELLOWISH BROWN.	2.69	0.10%			
(FC-2 UPPER) LIMESTONE - HARD, FINE-GRAINED, DENSE, POTENTIAL WEAK STYLOLITIC BEDDING PLANES, SEMI-CONCHOIDAL FRACTURES, DARK YELLOWISH BROWN. (FC-3L) (FC-4)	2.70 2.66 2.69	0.20% 0.68% 0.30%			
ARGILLACEOUS DOLOMITIC LIMESTONE-80%; HIGHLY ARG. DOLOMITIC LIMESTONE-3%; LAMINATED ARG. DOL. LIMESTONE - 3%; LIMESTONE-6%; CHERT-8%.	2.64 TO 2.67	0.6% 1.5%	2.1% TO 11.9%	18.1% TO 22.1	17%
DOLOMITE - HARD. MASSIVE, FINE-GRAINED, DENSE, NUMEROUS VUGS, OLIVE GRAY. DOLOMITIC LIMESTONE - HARD, FINE-GRAINED, DENSE, CONTAINS ARGILLACEOUS STREAKS, SHALY BEDDING SEAMS. GYPSUM NODULES. DARK YELLOWISH BROWN.	2.63 TO 2.66	0.81 TO 1.34%			
DOLOMITE - HARD. FINE-GRAINED. SUGARY-TEXTURED, DENSE. DARK YELLOWISH BROWN. DOLOMITIC LIMESTONE - HARD, MEDIUM-GRAINED. DENSE TO SLIGHTLY POROUS. LIGHT BROWNISH GRAY.					
	2.57	1.0			
QUARTZ-43%; LIMESTONE AND DOLOMITE-6%; SANDSTONE AND SILTSTONE-22%; IGNEOUS-8%; POTENTIALLY REACTIVE CHERT-15%; WEATHERED ROCK FRAGMENTS-1%; SHALE-3%; SHELLS-1%.	2.61	0.98%	12%		5%

ORY TESTING

ESULTS

F SE PART	L W PART	SO PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
						PETROGRAP
[illegible] [illegible] [illegible]	NONE					THE PETRO OF THE TH LOW ALKAL
				SPALLING OF SHALY BEDDING SURFACE.		
					SPALLING OF SHALY BEDDING PLANE SURFACE SPALLING OF SHALY BEDDING PLANE SURFACE	
[illegible]	NONE					THIS MATE
				NO EFFECT	NO EFFECT	
						C N SU
[illegible]	NONE				NOTE: LOW ALKALI CEMENT REQUIRED FOR CONCRETE.	U TO

REMARKS
ETROGRAPHIC ANALYSIS AND GRADING ONLY.
E PETROGRAPHIC ANALYSIS IS BASED ON THE AVERAGE PERCENTAGE : THE THREE N.Y.S. STONE SIZES. FOR CONCRETE MIX DESIGNS W ALKALI CEMENT IS REQUIRED.
HIS MATERIAL EXCAVATED FROM EAST QUARRY.

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB NO.	
STANDARD SLAG CO. QUARRY AT MARBLEHEAD, OH	LUCAS DOLOMITE		ORD 103/69.607C	DOLO YELL
			ORD 103/72.606C	LIMES CARB
				DOLO
				DOLO SLIGH
				DOLO FINE-
TRI COUNTY LIMESTONE CO. QUARRY AT MARSEILLES, OH	TYMOCHTEE FORMATION (DOLOMITE)		ORD 103/72.606C	DOLO MEDI
				DOLO SUB-
				DOLO PORO
U.S. GYPSUM CO. QUARRY AT GENOA, OH	NIAGARAN DOLOMITE		ORD 103/72.606C	DOLO ANCE, MEDI
			ORD 103/72.606C	DOLO WHITE
			ORD 103/72.606C	DOLO CLEAR

SUMMARY SHEET FOR LABORATORY

NO	PETROGRAPHIC ANALYSIS	SP GRAV	ABS	$MgSO_4$	L A A	F8E P
		TEST RESULT				
7C	DOLOMITE - HARD, VERY FINE-GRAINED DENSE, IRREGULAR FRACTURE, DARK YELLOWISH BROWN WITH VERY LIGHT TAN BLOTCHES.	2.62	2.01%			
6C	LIMESTONE - 6%, SANDY DOLOMITIC LIMESTONE - 8%, DOLOMITIC LIMESTONE -85%, CARBONACEOUS SHALE - 1%.	2.59	3.53%		32%	21%
	DOLOMITE - 81%, LIMESTONE - 19%	2.62	2.74%	3%	26%	8%
	DOLOMITIC LIMESTONE - HARD, MEDIUM-GRAINED, SUGARY-TEXTURED. DENSE TO SLIGHTLY POROUS, ABSORBENT, SUB-BLOCKY FRACTURE, MODERATE BROWNISH GRAY.	2.64	1.78%			
	DOLOMITIC LIMESTONE - HARD, FINE-GRAINED, SUB-LITHOGRAPHIC TEXTURE, FINE SIZED OOLITES, SUB-CONCHOIDAL FRACTURE, PALE YELLOWISH BROWN.	2.75	0.68%			
C	DOLOMITE - MODERATELY HARD, FINE-GRAINED, POROUS, IRREGULAR FRACTURE, MEDIUM GRAY WITH MINOR WHITE MOTTLING.	2.69	0.68%			
	DOLOMITE - MODERATELY HARD, MEDIUM-GRAINED, SUGARY-TEXTURED, POROUS, SUB-BLOCKY FRACTURE, WHITE WITH LIGHT GRAY MOTTLING.	2.63	1.13%			
	DOLOMITE - MODERATELY HARD, FINE TO MEDIUM-GRAINED, SUGARY-TEXTURED, POROUS, ABSORBENT, SUB-BLOCKY TO IRREGULAR FRACTURE, MEDIUM GRAY.	2.57	1.84%			
C	DOLOMITE - MODERATELY HARD, FINE-GRAINED WITH ALMOST BRECCIATED APPEARANCE. MEGAPOROUS AND VUGGY, IRREGULAR FRACTURE, YELLOWISH GRAY WITH MEDIUM GRAY MOTTLING.	2.54 TO 2.69	2.05 TO 4.62%			
C	DOLOMITE - HARD, FINE-GRAINED, VUGGY POROSITY CONTAINS CALCITE AND GYPSUM WHITE TO LIGHT TAN.	2.72	1.8%	5%	41%	9%
	DOLOMITE - HARD, FINE-GRAINED, VUGGY POROSITY, SOME VUGS FILLED WITH CLEAR CALCITE. VERY LIGHT GRAY, MOTTLED.	2.72	1.65%	19%		16%
		2.71	1.91%	4%	28%	6%

RY TESTING

SULTS						
F&E PART	L W PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
				NO EFFECT	NO EFFECT	
21%	NONE	NONE	NONE			F.M. - 2.72.
18%						TESTED FOR CO
					NO EFFECT	
				NO EFFECT		TESTED FOR RI ABS-2.71[illegible]).
				NO EFFECT	PARTING OF ONE STYLOLITE.	TWO SAMPLES F WET-DRY FREEZ
				NO EFFECT	NO EFFECT	
				NO EFFECT	NO EFFECT	
				NO EFFECT	NO EFFECT	
[illegible]%				(NOTE: SAMPLE TESTED FOR CELL FILL)		
[illegible]%	NONE			(NOTE: SAMPLE TESTED FOR FINE AGGREGATE FOR CONCRETE; FM-2.99)		
[illegible]%	NONE			(NOTE: SAMPLE TESTED FOR COARSE AGGREGATE FOR CONCRETE)		

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REMARKS
2.72. TESTED FOR FINE AGGREGATE FOR CONCRETE.
FOR COARSE AGGREGATE FOR CONCRETE.
FOR RIPRAP AND LARGER SIZE STONE (SAMPLE SS-3: SG-2.57: 71%).
PLES FROM SECOND LIFT TESTED. NEITHER EFFECTED BY FREEZE-THAW. SG-2.44: ABS-2.92

CATTARAUGUS HARBOR, NEW YORK

OHIO MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

O ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO.
NATIONAL LIME AND STONE COMPANY QUARRY AT MARION, OH	COLUMBUS DOLOMITE		ORD 103/73.606C
NATIONAL LIME AND STONE COMPANY QUARRY AT SPORE, OH	COLUMBUS DOLOMITE		ORD 103/73.606C
CHAS. PFIZER, INC. QUARRY AT GIBSONBURG, OH	NIAGARAN DOLOMITE		ORD 103/72.606C
SANDUSKY CRUSHED STONE CO. QUARRY AT PARKERTOWN, OH	LUCAS AND COLUMBUS DOLOMITE		ORD 103/72.606C
[illegible] INC. [illegible] AT THOMPSON, OH	GLACIAL DEPOSIT		HERRON TESTING H15707

SUMMARY SHEET FOR LABORATOR

.NO.	TEST RESU					
	PETROGRAPHIC ANALYSIS	SP. GRAV.	ABS.	$MgSO_4$	L.A.A.	F&E
.606C	DOLOMITIC LIMESTONE - MODERATELY HARD, FINE-GRAINED, DENSE TO MICROPOROUS, SUB-BLOCKY FRACTURE, LIGHT YELLOWISH GRAY WITH MEDIUM GRAY MOTTLING.	2.73	0.69%			
.606C	DOLOMITE - MODERATELY HARD, FINE-GRAINED WITH SUGARY-TEXTURE, MICROPOROUS, ABSORBENT, YELLOWISH GRAY WITH SLIGHT DARK GRAY MOTTLING.	2.64	2.13%			
	DOLOMITE - MODERATELY HARD, FINE TO MEDIUM-GRAINED, MICROPOROUS, ABSORBENT, BLOCKY FRACTURE, YELLOWISH GRAY.	2.63	1.50%			
.606C	DOLOMITE - MODERATELY HARD TO HARD, FINE TO MEDIUM-GRAINED, SUGARY-TEXTURED, SUB-BLOCKY TO BLOCKY FRACTURE, MICROPOROUS TO POROUS, GRAYISH ORANGE TO YELLOWISH GRAY.	2.45 TO 2.56	3.0% TO 5.13%			
.606C	LIMESTONE - 11%, DOLOMITIC LIMESTONE - 66%, ARGILLACEOUS DOLOMITIC LIMESTONE - 1%, FOSSILIFEROUS DOLOMITIC LIMESTONE - 20%, CARBONACEOUS SHALE - 1%, CHERT - 1%.	2.62	2.0%	36%		14%
	DOLOMITIC LIMESTONE - 53%, FOSSILIFEROUS DOLOMITIC LIMESTONE - 33%, FOSSILIFEROUS LIMESTONE - 9%, SHALY DOLOMITIC LIMESTONE - 2%, CHERTY DOLOMITIC LIMESTONE - 2%, CHERT - 1%.	2.65	1.99%	2%	29%	6%
	DOLOMITIC LIMESTONE - HARD, FINE-GRAINED, EVEN-TEXTURED, DENSE, BLOCKY FRACTURE, MODERATE BROWNISH GRAY.	2.69	0.44%			
	CHERTY LIMESTONE - HARD, FINE-GRAINED, VERY EVEN-TEXTURED, DENSE, BLOCKY TO CHONCHOIDAL FRACTURE, MODERATE BROWNISH GRAY	2.42	7.84%			
	LIMESTONE - HARD, COARSE-GRAINED, DENSE, FOSSILIFEROUS, SUB-CONCHOIDAL TO SUB-BLOCKY FRACTURE, PAPER-THIN, SHALY, INTERNAL BEDDING SEAMS THAT CONTROL PARTING. MODERATE OLIVE GRAY.	2.72	0.48[illegible]			
	DOLOMITE - HARD, FINE-GRAINED, EVEN-TEXTURED, MICROPOROUS, ABSORBENT, SUB-BLOCKY FRACTURE, PAPER-THIN, WAVY, DISCONTINUOUS CARBONACEOUS SEAMS, DARK YELLOWISH BROWN.	2.67	1.54[illegible]			
		2.59	0.8[illegible]	NO. 504 117%		

ORY TESTING

ESULTS						
F&E PART	L W PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
				NO EFFECT	NO EFFECT	
				NO EFFECT	PARTING OF STYLOLITE	
				NO EFFECT	NO EFFECT	
				NO EFFECT	NO EFFECT	
14%	NONE	NONE	NONE			TESTED FOR
6%	NONE	NONE	NONE			TESTED FOR
				NO EFFECT		
					COMPLETE DISINTEGRATION OF THE LARGE CHERT NODULES AFTER ONE FREEZE-THAW CYCLE.	CONTAINS L BENT AND M TEST.
				OPENING AND PARTING OF THIN SHALY BEDDING SEAMS.		
					TIGHT HAIRLINE CRACKS PARALLEL TO BEDDING.	
				NO. 400 SILICA SAND		

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REMARKS
[illegible]STED FOR FINE AGGREGATE FOR CONCRETE
[illegible]STED FOR CELL FILL AND COARSE AGGREGATE FOR CONCRETE
[illegible]NTAINS [illegible] CHERT NODULES THAT ARE CHALKY [illegible] [illegible]NT AND [illegible] SUSCEPTIBLE TO BREAKDOWN UNDER [illegible] [illegible]ST.

CATTARAUGUS HARBOR, NEW YORK

OHIO MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

PLATE 32

SOURCE	FORMATION	PROPOSED USE	LAB.
INDIANA LIMESTONE QUARRY AT BEDFORD, IND	SALEM FORMATION (LIMESTONE)		ORD 103/73.61

SUMMARY SHEET FOR LABORAT

LAB.NO.	TEST R				
	PETROGRAPHIC ANALYSIS	SP.GRAV.	ABS.	$MgSO_4$	L.A.A.
ORD 103/73.612C	LIMESTONE - (CALCARENITE) - MODERATELY HARD, MEDIUM-GRAINED, VERY POROUS EVEN-TEXTURED, OOLITES, FOSSIL DETRITUS, SUB-BLOCKY FRACTURE, GRAYISH ORANGE	2.40 TO 2.49	2.82 TO 3.82%		
	PSUEDOOLITIC LIMESTONE - MODERATELY HARD, FINE-GRAINED, EVEN-TEXTURED, DENSE, CONSISTS OF WELL-SORTED, ROUNDED CALCAREOUS GRAINS COATED WITH A THIN LAYER OF CARBONATE MUD AND LOOSELY PACKED IN A MATRIX OF CLEAR CALCITE, SUB-BLOCKY FRACTURE, BROWNISH GRAY.	2.38	6.11%		

ATORY TESTING

RESULTS

A.A.	F&E PART	L.W. PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
					NO EFFECT	SOME SURFACE SPALLING	
						SPECIMEN SPLIT IN HALF. NO SOFT SEAM OR PLANE OF WEAKENESS IS EVIDENT.	NOTE

	REMARKS
CYCLES)	
, NO SOFT NESS IS	NOTE LOW SPECIFIC GRAVITY FOR THIS SOURCE.

CATTARAUGUS HARBOR, NEW YORK

INDIANA MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB NO.
HOUDAILLE CONST. MATERIALS, INC. QUARRY AT CLARENCE, N.Y.	ONONDAGA LIMESTONE		ORD 103/71.612C
			ORD 103/72.606C
LANCASTER STONE PRODUCTS QUARRY AT CLARENCE, N.Y.	ONONDAGA LIMESTONE		ORD 103/68.605C
			NYS DOT 70AR2
MEDINA SANDSTONE QUARRY INC. DIVISION OF GREATER BUFFALO PRESS CO. QUARRY AT HULBERTON, N.Y.	GRIMSBY FORMATION (SANDSTONE)		ORD 103/73.630C ORD 103/74.604C
NIAGARA STONE DIVISION OF GREATER BUFFALO PRESS CO. QUARRY AT NIAGARA FALLS (PLETCHERS CORNERS), N.Y.	LOCKPORT DOLOMITE		ORD 103/71.612C
PINE HILLS CONCRETE MIX CO. PIT AT LANCASTER, N.Y.	NATURAL SAND		NYS DOT 70AF185
PINE HILLS CONCRETE MIX CO. PIT AT NEWSTEAD, N.Y.	NATURAL SAND		NYS DOT 71AF257
PINE HILLS CONCRETE MIX CO. PIT AT NEWSTED, N.Y.	NATURAL SAND		ORD 101/66.310C

SUMMARY SHEET FOR LABORATO

B NO.	TEST RES					
	PETROGRAPHIC ANALYSIS	SP. GRAV	ABS.	MgSO₄	L. A. A.	F&
1.612C	CHERTY DOLOMITIC LIMESTONE - HARD, FINE-GRAINED, MODERATELY DOLOMITIC, CHERTY, DENSE, BLOCKY FRACTURE, BROWNISH GRAY WITH LIGHT GRAY MOTTLING.	2.74	0.40%			
	CHERT - HARD, DENSE, SMALL SPLOTCHES OF DOLOMITE LIMESTONE SCATTERED THROUGHOUT, MEDIUM GRAY WITH DARK BROWN MOTTLING.	2.65	1.21%			
72.606C	LIMESTONE - 12%, ARGILLACEOUS DOLOMITIC LIMESTONE - 18%, HIGHLY ARGILLACEOUS DOLOMITIC LIMESTONE - 3%, CHERTY DOLOMITIC LIMESTONE - 40%, CHERT - 26%.	NYS#1-2.66 NYS#2-2.68 NYS#3-2.67	0.56% 0.44% 0.37%	1.0	20	18 19 12
08.605C	LIMESTONE - HARD, FINE TO COARSE-GRAINED, DENSE, CHERTY, YELLOWISH BROWN TO DARK YELLOWISH BROWN.	2.68 TO 2.71	TRACE			
OT 2		2.65	0.5%			
3.630C 4.604C	SANDSTONE - VERY HARD, FINE-GRAINED, VERY EVEN TEXTURED, DENSE, TIGHTLY PACKED IN A MIXTURE OF CALCEROUS AND FERRUGINOUS CEMENTS.	2.51	1.40%			
1.612C	DOLOMITE - HARD, FINE-GRAINED, SUGARY-TEXTURED, DENSE, VUGS FILLED WITH GYPSUM, SPHALERITE AND FLUORITE, BLOCKY TO CONCHOIDAL FRACTURE, BROWN TO DARK YELLOWISH BROWN.	2.67 TO 2.80	0.26% TO 1.09%			
DT 15	LIMESTONE AND SANDSTONE	2.64	1.4%			
IT 37		2.64	1.8%			
.310C	LIMESTONE - 29%; QUARTZ, QUARTZITE AND SANDSTONE-57%, IGNEOUS AND METAMORPHICS - 10%, CHERT - 1%, WEATHERED LIMESTONE - 3%, FRIABLE SANDSTONE AND SILTSTONE - TRACE, MICA - TRACE.	2.66	0.95%	18.9%		

TORY TESTING

RESULTS

FINE PART	L.W. PART	SO PART	CLAY LUMPS	WET-DRY 80 CYCLES	FREEZE THAW 3[illegible] CYCLES	
				SPALLING OF SHALY BEDDING PLANE SURFACE.	NO EFFECT	
				NO EFFECT	NO EFFECT	
[illegible]	NONE					THE PETRO[illegible] OF THE TH[illegible] CORPS OF [illegible]
				BREAKAGE ALONG SHALY BEDDING SEAM.	NO EFFECT	NINE SAMP[illegible]
						TESTED BY [illegible] MENT REQU[illegible]
				NO EFFECT	NO EFFECT	STONE MATE[illegible] NOT ACCEPT[illegible]
				GYPSUM NODULES PARTIALLY DISSOLVED.	DEVELOPMENT OF TIGHT CRACKS ALONG SHALE SEAMS. PARTIAL DISSOLUTION OF GYPSUM NODULES	SELECTIVE [illegible] EXCESSIVE.
						TESTED BY [illegible]
						TESTED BY [illegible]

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REMARKS
PETROGRAPHIC ANALYSIS IS BASED ON THE AVERAGE PERCENTA[GE OF] THE THREE STONE SIZES. LOW ALKALI CEMENT REQUIRED BY [COR]PS OF ENGINEERS.
[TH]E SAMPLES WERE TESTED.
[TE]STED BY NYS DEPARTMENT OF TRANSPORTATION. LOW ALKALI [CEMEN]T REQUIRED BY CORPS OF ENGINEERS.
[STO]NE MATERIALS WITH ARGILLACEOUS SHALE BANDS AND PARTIN[GS NO]T ACCEPTABLE.
[SE]LECTIVE QUARRYING MAYBE REQUIRED WHEN GYPSUM NODULES ARE [EX]CESSIVE.
[TE]STED BY NYS DEPARTMENT OF TRANSPORTATION
[TE]STED BY NYS DEPARTMENT OF TRANSPORTATION.

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U S ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

PLATE C23

SOURCE	FORMATION	PROPOSED USE	LAB. NO.	
COUNTY LINE STONE CO., INC. QUARRY AT AKRON, N.Y.	ONONDAGA LIMESTONE		ORD 103/71.612C	LI CHE
COUNTRY SIDE SAND AND GRAVEL, INC. PIT AT SOUTH DAYTON, N.Y.	GLACIAL DEPOSITION		ORD 103/75.606B	QUA 30% SHA
B.R. DEWITT PIT NO. 5 AT RIDGEWAY, N.Y.	SAND		ORD 103/72.610C ORD 103/74.624C	QUA SA QUA IGN
DOLOMITE PRODUCTS, INC. QUARRY AT GATES CENTER, N.Y	LOCKPORT DOLOMITE		ORD 103/72.610C	SIL SIL DOL YEL
				SHA NUM DOL SHA
				DOL BRO
DOLOMITE PRODUCTS, INC. QUARRY AT PENFIELD, N.Y	LOCKPORT DOLOMITE		ORD 103/73.603C	DOL BRO DOL PIN
CAYUGA CRUSHED STONE INC. QUARRY AT SOUTH LANSING, N.Y.	TULLY LIMESTONE		ORD 101/67.358C	LIM ARG
ABRAM CLEASON PIT AT PALMYRA, N.Y.	GLACIAL SANDS AND GRAVEL		NYS DOT 70AF142	

SUMMARY SHEET FOR LABORATORY

NO.	TEST RESUL					
	PETROGRAPHIC ANALYSIS	SP.GRAV.	ABS.	$MgSO_4$	L.A.A.	F&E
812C	LIMESTONE - HARD. FINE TO MEDIUM-GRAINED, DENSE, SLIGHTLY DOLOMITIC, CHERT NODULES, DARK GRAY TO DARK BROWNISH GRAY.	2.69 TO 2.70%	0.04 TO 0.14%			
.606B	QUARTZ - 31% - LIMESTONE AND DOLOMITE - 31%; SANDSTONE AND SILTSTONE - 30%; IGNEOUS AND METAMORPHIC - 1%; CHERT (POTENTIALLY REACTIVE) - 0.5%; SHALE - 6%	2.60	1.3	21%		17%
610C 624C	QUARTZ - 39%; WEATHERED ROCK FRAG. 2%; LIMESTONE AND DOLOMITE -5%; SANDSTONE AND SILTSTONE -40%; IGNEOUS AND METAMORPHIC -14%. QUARTZ - 45%; LIMESTONE AND DOLOMITE-6%, SANDSTONE AND SILTSTONE-36%; IGNEOUS AND METAMORPHIC-12%; CHERT-TRACE; WEATHERED ROCK FRAGS-1%.	2.58	1.97%	15%		3%
610C	SILTY DOLOMITE - HARD, FINE-GRAINED, SUGARY-TEXTURED, DENSE, FINE QUARTZ SILT WITH DOLOMITE MATRIX, DARK YELLOWISH BROWN. DOLOMITE - HARD, FINE-GRAINED, SUGARY-TEXTURE, DISCONTINUOUS SHALY SEAMS, YELLOWISH BROWN.	2.75	0.92 TO 1.03%	6%	22%	16 TO 22%
	SHALY DOLOMITE - HARD, FINE TO MEDIUM-GRAINED, SUGARY-TEXTURED, DENSE, NUMEROUS SHALY SEAMS, DARK YELLOWISH BROWN. DOLOMITIC LIMESTONE - HARD, FINE-GRAINED, DENSE, NUMEROUS PAPER-THIN SHALE SEAMS, MEDIUM DARK GRAY.					
	DOLOMITE - HARD, FINE TO MEDIUM-GRAINED, SUGARY-TEXTURED, DARK YELLOWISH BROWN WITH PALE YELLOWISH BROWN BANDS,					
603C	DOLOMITE - MODERATELY HARD, FINE-GRAINED TO DENSE, PALE TO DARK YELLOWISH BROWN. DOLOMITE - HARD, FINE-GRAINED, SUGARY-TEXTURED, VERY DENSE, MEDIUM PINKISH GRAY.	2.62 TO 2.74	0.81 TO 1.19%			
358C	LIMESTONE - LIMESTONE-60%; MODERATELY ARGILLACEOUS LIMESTONE-37%; ARGILLACEOUS LIMESTONE-3%.	2.70	.31	4.2%	21%	7%
		2.58	1.6			

ORATORY TESTING

ST RESULTS						
L.A.A.	F&E PART	L.W PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)
					SPALLING OF SHALY BEDDING PLANE SURFACE-SLIGHT PARTING OF SHALE BEDDING PLANE.	NO EFFECT
	17%					
	3%		NONE			
22%	16 TO 22%	NONE	NONE		SLIGHT SPALLING OF THE SHALY BEDDING PLANE SURFACES.	SLIGHT PARTING OF THE SHALY BEDDING SEAMS.
					SLIGHT PARTING OF QUARRYING FRACTURES.	
21%	7%					
						TESTED BY NYS DEPARTMENT OF TRANSPORTATION.

YCLES)	REMARKS
	FOR CONCRETE MIX DESIGNS LOW ALKALI CEMENT IS REQUIRED.
	F.M. VARIES FROM 2.[illegible]9 TO 2.56. SHALE CONTENT VARIES FROM 6 TO 14%.
	PETROGRAPHIC EXAMINATION ONLY.
ALY	
OF	

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO.
BUFFALO SLAG CO. PIT AT MACHIAS, N.Y.	GLACIAL DEPOSITION		ORD 103/72.606C
BUFFALO SLAG CO. PIT AT ALFRED STA., N.Y.	GLACIAL DEPOSITION		ORD UNKNOWN
			ORD 103/74.617C
CAYUGA CRUSHED STONE CO. SOUTH LANSING, N.Y.	TULLY FORMATION (LIMESTONE)		ORD 103/66.600C
CONCRETE MATERIALS, INC. SWEDEN, N.Y.	LOCKPORT DOLOMITE		ORD 101/71.362C ORD 71153
CONCRETE MATERIALS, INC. MANCHESTER, N.Y.	ONONDAGA LIMESTONE		ORD 103/73.630C

SUMMARY SHEET FOR LABORATOR

.NO.	TEST RESU					
	PETROGRAPHIC ANALYSIS	SP.GRAV.	ABS.	$MgSO_4$	L.A.A.	F&
2.606C	QUARTZ-24%; SANDSTONE AND SILTSTONE-50%; LIMESTONE AND DOLOMITE-10%; IGNEOUS AND METAMORPHIC-5%; WEATHERED ROCK FRAGMENTS-1%; SHALE-6%; CHERT (POTENTIALLY REACTIVE)-4 %.	2.59	1.50%	19%		
[illegible]	QUARTZ AND QUARTZITE - 8%; LIMESTONE AND DOLOMITE - 20%; SANDSTONE AND SILTSTONE - 54%; IGNEOUS AND METAMORPHIC - 5%; CHERT - 3%; WEATHERED ROCK FRAGMENTS - TRACE; SILTY SHALE - 7%.	2.57	1.7%			
	STONY VESCILUR SLAG - 66%; STONY SLAG - 32%; PARTLY GLASSY SLAG - 2%.	2.60	5.1%			
	STONY VESICULAR SLAG (A-68%, B-67%) STONY SLAG (A-27%, B-25%) PARTLY GLASSY SLAG (A-20%, B-3%) PARTIALLY BURNED CINDER (A-TRACE, B-TRACE) IRON NODULES (A-3%, B-5%)	A-2.24 2.40	A-5.6% 4.7%	A-1%	A-36%	A-6
617C	STONY SLAG - DENSE TO SLIGHTLY POROUS; STONY VESICULAR SLAG - HIGHLY POROUS, SPONGE-LIKE; IRON OXIDE NODULES - SOFT, ABSORBENT.	2.4	5.6% TO 7.6%			
000C	LIMESTONE -HARD, FINE-GRAINED, SUB-LITHOGRAPHIC IN TEXTURE, DENSE, SLIGHTLY FOSSILIFEROUS, OCCASSIONAL CHERT NODULE, WAVY SHALE SEAMS, DARK OLIVE GRAY.	2.70				
362C	DOLOMITIC LIMESTONE - 70%; SHALY, DOLOMITIC LIMESTONE - 4%; FOSSILIFEROUS LIMESTONE - 26%. DOLOMITIC LIMESTONE, HARD FINE-GRAINED, DENSE, CONTAINS THIN, ARGILLACEOUS BANDS.	2.76 2.74	.49 TO 1.05% 0.88%	6.78% 10.0%	21.2% 21.3%	
00C	CHERTY DOLOMITIC LIMESTONE-MODERATELY HARD, VERY FINE-GRAINED, LITHOGRAPHIC TEXTURED, DENSE, CONTAINS LARGE NODULES OF LIGHT GRAY, PORCELLANEOUS CHALCEDONIC CHERT, SUB-CONCHOIDAL FRACTURE, MEDIUM BROWNISH GRAY.	2.68	0.23%			

ATORY TESTING

RESULTS							
A.A.	F&E PART	L.W. PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
	4%	NONE	NONE	NONE			FAI FOR
							TEST ANAL
	3%						TEST
%	A-6 7%	A-3.83%					(A)- (B)-
					NO EFFECT	HIGHLY VESICULAR SLAG BROKE DOWN. OTHER SAMPLES WERE NOT EFFECTED.	SPEC AND QUAL
					SLIGHT PARTING ALONG SHALE BEDDING PLANES	PARTING ALONG THE SHALE BEDS AND SLIGHT SURFACIAL SPALLING.	
% %							TESTE ORD 7
					NO EFFECT		FOR C TESTE

REMARKS

FAIR QUALITY FOR USE AS FINE AGGREGATE. TESTS RAN ON -3/8
FOR CONCRETE MIX DESIGNS LOW ALKALI CEMENT IS REQUIRED.

TESTED BY NYS DEPARTMENT OF TRANSPORTATION. PETROGRAPHIC ANALYSIS ONLY BY ORD LAB

TEST RAN ON -2 1/2 INCH MATERIAL.

(A)-TEST RAN ON 3/4 TO 1 1/2 INCH MATERIAL.

(B)-TEST RAN ON #4 TO 3/4 INCH MATERIAL.

SPECIFIC GRAVITY FROM CHUNK SAMPLES, SUITABLE FOR CORE STONE AND CELL FILL. PELLITIZED SLAG NOT ACCEPTABLE - QUESTIONABLE QUALITY.

TESTED FOR CONCRETE AGGREGATE.

ORD 71153 TESTED FOR CELL FILL

FOR CONCRETE MIX DESIGNS LOW ALKALI CEMENT IS REQUIRED.
TESTED FOR RIPRAP

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO.
GENERAL CRUSHED STONE, INC. QUARRY AT SODUS, N.Y.	LOCKPORT DOLOMITE		ORD 103/72.607C ORD 103/73.630C
			ORD 101/71.358C ORD 103/74.613C
GENERAL CRUSHED STONE, INC. QUARRY AT HONEOYE FALLS, N.Y.	ONONDAGA LIMESTONE		ORD 103/72.602C
GENESEE STONE PRODUCTS QUARRY AT STAFFORD, N.Y.	ONONDAGA LIMESTONE		ORD 103/72.602C
HANOVER SAND AND GRAVEL, INC. PIT AT HANOVER, N.Y.	NATURAL SAND AND GRAVEL		NYS DOT 70AF171
GERNATT GRAVEL PR[illegible]UCTS PIT AT COLLINS, [illegible]	GLACIAL DEPOSITION		NYS DOT 70AF188
GENESEE STONE PRODUCTS QUARRY AT STAFFORD, N.Y.	ONONDAGA LIMESTONE		ORD 103/74.610C

SUMMARY SHEET FOR LABORATOR

(L)AB. NO.	TEST RESU(LTS)					
	PETROGRAPHIC ANALYSIS	SP. GRAV.	ABS.	$MgSO_4$	L.A.A.	F&
72.607C 73.630C	DOLOMITE - 97.1%; ARGILLACEOUS DOLOMITE - 2.9%; (DOLOMITE-HARD, FINE GRAINED, SUGARY-TEXTURED, THIN, WAVY, SHALY INTERNAL BEDDING SEAMS CONTROL PARTING, SUB-CONCHOIDAL TO SUB-BLOCKY FRACTURE, DARK BROWN. DOLOMITE-HARD, FINE-GRAINED, VERY EVENSUGARY-TEXTURE, TOUGH W/ BLOCKY FRACTURE, DARK YELLOWISH BROWN.					
71.358C 74.613C	DOLOMITE - HARD, FINE-GRAINED, SUGARY-TEXTURED, DENSE, THIN, WAVY, SHALY INTERNAL BEDDING SEAMS CONTROL PARTING. DOLOMITE - 100%, CHERTY DOLOMITE - TRACE	NYS#1-2.73 NYS#2-2.73 NYS#3-2.71	1.38% 1.25% 1.11%	2.29 2.29	23.5	NYS NYS NYS 3
72.602C	CHERTY LIMESTONE - HARD, FINE-GRAINED, LITHOGRAPHIC-TEXTURED, DENSE, SLIGHTLY DOLOMITIC, PORCELLANEOUS CHERT, SEMI-CONCHOIDAL FRACTURE, DARK YELLOWISH BROWN.	2.66 TO 2.70	0.35 TO 0.41			
72.602C	CHERTY LIMESTONE - HARD, FINE-GRAINED, SEMI-LITHOGRAPHIC IN TEXTURE, DENSE, CONTAINS BROWNISH GRAY PORCELLANEOUS CHERT, DARK YELLOWISH BROWN.	2.69	0.11%			
	LIMESTONE - MODERATELY HARD, COARSE-GRAINED, EVEN TEXTURED, DENSE, FOSSILIFEROUS, DARK YELLOWISH BROWN. CHERTY LIMESTONE - MODERATELY HARD, MEDIUM-GRAINED, FOSSILIFEROUS, DARK YELLOWISH BROWN.	2.68 TO 2.71	0.10% TO 0.33%			
T I		2.53	2.4%			
T B		2.57	1.8%			
.610C	LIMESTONE (L-1-1) MODERATELY HARD, COARSE-GRAINED, EVEN-TEXTURED, DENSE, FOSSIL DEBRIS, SUB-CONCHOIDAL FRACTURE, DARK YELLOWISH BROWN. CHERTY LIMESTONE (L-1-2) MODERATELY HARD, MEDIUM-GRAINED, DENSE, FOSSIL DEBRIS, SUB-BLOCKY FRACTURE, PORCELLANEOUS CHERT, DARK YELLOWISH BROWN, LIMESTONE (L-1-3) MODERATELY HARD, MEDIUM-GRAINED. VERY EVEN-TEXTURED, SUB-BLOCKY TO SUB CONCHOIDAL FRACTURE, DARK YELLOWISH BROWN. LIMESTONE (L-1-4) SAME AS L-1-2 ONLY SLIGHTLY ARGILLACEOUS AND NO CHERT. LIMESTONE (L-3-1) MODERATELY HARD, HIGHLY ARGILLACEOUS, FINE-GRAINED, EVEN-TEXTURED, DENSE, HACKLY FRACTURE, DARK YELLOWISH BROWN. LIMESTONE (L-3-2) HIGHLY ARGILLACEOUS AND CHERTY, SAME AS L-3-1. LIMESTONE (L-3-3) MODERATELY HARD, HIGHLY ARGILLACEOUS AND CHERTY, FINE-GRAINED, DENSE, CONTAINS CHERT NODULES AND SHALE PARTINGS; SHALE SEAMS CONTROL PARTING, BROWNISH BLACK. CHERT (L-3-4) DENSE, PORCELLANEOUS, FRACTURED, DARK GRAY WITH LIGHT GRAY MOTTLING.	L-1-1 2.68 L-1-2 2.68 L-1-3 2.71 L-1-4 2.71 L-3-1 2.69 L-3-2 2.68 L-3-3 2.65 L-3-4 2.64	0.27% 0.33% 0.25% 0.10% 0.13% 0.22% 0.69% 0.35%			

RATORY TESTING

T RESULTS

L.A.A	F&E PART	L W PART	SO PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)
23.5	NYS#1-15% NYS#2-11% NYS#3-15% 33%					
					NO EFFECT; HOWEVER CHERT-LIMESTONE CONTACTS BROKEN DUE TO DIFFERENTIAL THERMAL EXPANSION	CHERT-LIMESTONE CONTACTS PARTIALLY BROKEN DUE TO DIFFERENTIAL THERMAL EXPANSION CHERT SEVERELY FRACTURED.
					CHERT LIMESTONE CONTACTS BADLY BROKEN ON SURFACE.	NO EFFECT
					NO EFFECT	NO EFFECT
					(L-1-1) NO EFFECT (L-1-2) NO EFFECT	(L-1-3) NO EFFECT (L-1-4) NO EFFECT.
					(L-3-2) TIGHT FRACTURES DEVELOPED. THROUGH CHERT NODULES. (L-3-3) PARTING ALONG SHALY SEAMS.	(L-3-1) TIGHT FRACTURES DEVELOPED. (L-3-4) CHERT FRACTURED AND SPALLED.

CLES)	REMARKS
	PETROGRAPHIC ANALYSIS ONLY (LEDGE ROCK)
	COARSE AGGREGATE FOR CONCRETE. PETROGRAPHIC ANALYSIS ONLY (CONCRETE AGGREGATE)
AR- EREN- ERT	~~LOW ALKALI CEMENT REQUIRED BY CORPS OF ENGINEERS~~ SAMPLED AND TESTED FOR RIPRAP.
	MATERIAL FROM SECOND LIFT FOR CONCRETE MIXES. LOW ALKALI CEMENT REQUIRED BY THE CORPS OF ENGINEERS.
	MATERIAL FROM FIRST LIFT.
	TESTED BY NYS DEPARTMENT OF TRANSPORTATION.
	TESTED BY NYS DEPARTMENT OF TRANSPORTATION.
VELO- ED AND	

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB.NO.
ROYALTON STONE PRODUCTS, INC. QUARRY AT GASPORT, N.Y.	LOCKPORT DOLOMITE		ORD 103/71.612C
SPENCER AND HALEY, INC. PIT AT FREEDOM, N.Y.	GLACIAL DEPOSITION		ORD 103/75.606B
VALLEY SAND AND GRAVEL CORP. PIT AT SCOTTSVILLE, N.Y.	NATURAL SAND		NYS DOT 71AF35
WARREN BROS. DIVISION OF ASHLAND OIL CO. QUARRY AT CANOGA, N.Y.	ONONDAGA LIMESTONE		ORD 103/74.601C
SPENCER AND HALEY, INC. PIT AT FREEDOM, N.Y.	GLACIAL DEPOSITION		ORD 103/75.606B

SUMMARY SHEET FOR LABORATO

LAB. NO.	PETROGRAPHIC ANALYSIS	SP. GRAV.	ABS.	$MgSO_4$	L.A.A.	
		TEST RES				
/71.612C	DOLOMITE - HARD, MASSIVE, FINE-GRAINED, SCATTERED MICROPORES, DENSE, GRAYISH ORANGE. DOLOMITE - HARD, MEDIUM-GRAINED, EVEN-TEXTURED, VERY POROUS, YELLOWISH GRAY.	2.62 TO 2.65	1.16%			
/75.6068	QUARTZ AND QUARTZITE - TRACE LIMESTONE AND DOLOMITE - 44%; SANDSTONE AND SILTSTONE - 44%; IGNEOUS AND METAMORPHIC - 6%; CHERT (POTENTIALLY REACTIVE) - 2%; WEATHERED ROCK FRAGMENTS - 2%; SHALE - 2%	2.C2	1.63%	11%	20%	1
	COARSE AGGREGATE: QUARTZ AND QUARTZITE - 4%, LIMESTONE AND DOLOMITE - 3%, SANDSTONE AND SILTSTONE - 44%, IGNEOUS AND METAMORPHIC - 47%, WEATHERED SANDSTONE - 2%	2.61 TO 2.62	1.27 TO 1.47	11%	39%	12
DOT F35		2.60	2.2			
/74.601C	LIMESTONE - MODERATELY HARD, FINE-GRAINED, EVEN-TEXTURED, DENSE, SLIGHTLY DOLOMITIC, DARK BROWNISH GRAY. LIMESTONE - MODERATELY HARD, VERY FINE-GRAINED, SUB-LITHOGRAPHIC TO LITHOGRAPHIC TEXTURE, DENSE, SLIGHTLY DOLOMITIC, SLIGHTLY ARGILLACEOUS, DARK BROWNISH GRAY.	2.67 TO 2.71	0.02 TO 0.25%			
/75.6068	QUARTZ AND QUARTZITE - 36%: LIMESTONE AND DOLOMITE - 26 [illegible]; SANDSTONE AND SILTSTONE - 34 [illegible]; IGNEOUS AND METAMORPHIC - 2 [illegible]; CHERT - 1 [illegible] WEATHERED ROCK FRAGMENTS - 1%; SHALE - 1%	2.59	1.62%	19%		10

RATORY TESTING

T RESULTS

L.A.A.	F&E PART	L.W. PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
					NO EFFECT	NO EFFECT	
20%	11%						C
39%	12%	0.05					SA
							TE
					NO EFFECT	NO EFFECT	HA WE LI
	10%						FI

...LES)	REMARKS
	COARSE AGGREGATE FOR CONCRETE
	SANDSTONE AND SILTSTONE SHOWED HIGH LOSS IN SO_4 TEST.
	TESTED BY NYS DEPARTMENT OF TRANSPORTATION.
	HAIRLINE FRACTURES PRESENT IN THE SAMPLE BEFORE TESTING WERE UNAFFECTED BY THE DURABILITY TESTS. FIRST AND SECOND LIFTS ARE ONLY LIFTS ACCEPTABLE.
	FINE AGGREGATE FOR CONCRETE

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

1 4

SOURCE	FORMATION	PROPOSED USE	LAB.NO.	
FRANCE STONE CO. QUARRY AT MONROE, MI	BASS ISLAND FORMATION (DOLOMITE)		ORD 103/73.612C	DOL DEN YEL
				DOL POR YEL

SUMMARY SHEET FOR LABORATORY

	TEST RESULTS				
PETROGRAPHIC ANALYSIS	SP.GRAV.	ABS.	$MgSO_4$	L.A.A.	F&E PART
DOLOMITIC LIMESTONE - MODERATELY HARD, FINE-GRAINED, RUBBLY-TEXTURED, DENSE WITH VOIDS UP TO 1/2" DIAMETER, INCLINED STYLOLITES, MOTTLED, LIGHT YELLOWISH GRAY AND LIGHT MEDIUM GRAY.	2.72	1.09%			
DOLOMITIC LIMESTONE - MODERATELY HARD, FINE-GRAINED, MICROPORES AND MACROPORES, CLOSELY SPACED STYLOLITES, IRREGULAR FRACTURES, MOTTLED LIGHT YELLOWISH GRAY AND LIGHT MEDIUM GRAY.	2.62	1.43%			

Y TESTING

LTS

E PART	L.W. PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
				(FS-1-2) - DEVELOPMENT OF A FEW TIGHT FRACTURES.	SLIGHT SURFACE SPALLING	
				(FS-2-2) - A FEW TIGHT FRACTURES AND SOME SPALLING	NO EFFECT	

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SUMM

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TO ACCO

REMARKS

CATTARAUGUS HARBOR, NEW YORK

NEW YORK MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB. NO.
BROUGH STONE CO. QUARRY AT WEST MILLGROVE, OH.	NIAGARAN DOLOMITE		ORD 103/73.606C
CLEVELAND QUARRIES CO. QUARRY AT SOUTH AMHERST, OH	BEREA SANDSTONE		ORD 103/68.604C
			ORD 103/72.606C

SUMMARY SHEET FOR LABORATORY

O.	PETROGRAPHIC ANALYSIS	SP.GRAV.	ABS.	$MgSO_4$	L.A.A	F&E PA
						8
C	DOLOMITE - MODERATELY HARD, FINE TO MEDIUM-GRAINED, SUGARY-TEXTURED, POROUS AND ABSORBENT, RUBBLY, BRECCIA-LIKE STRUCTURE, PALE OLIVE GRAY WITH MEDIUM GRAY MOTTLING. DOLOMITE (KLINTITE) - RUBBLY TEXTURE WITH APPEARANCE OF BRECCIA WITH LITTLE MATRIX, POROUS, VUGGY, LIGHT YELLOWISH GRAY.	2.54 TO 2.66	1.71% TO 1.43%			
	SANDSTONE - HARD, MODERATELY FRIABLE, FINE-GRAINED, THIN-BANDED, POROUS, SUB-ANGULAR GRAINS OF FELDSPAR, FERRO-MAGNESIAN MINERALS, LIMESTONE AND LIMONITE LOOSELY PACKED AND POORLY CEMENTED BY SILICA, LIGHT GRAY.	2.23	6.28%			
	SANDSTONE - MODERATELY HARD, FRIABLE, MEDIUM-GRAINED, POROUS, ABSORBENT, WELL-SORTED, SUB-ROUNDED TO SUB-ANGULAR GRAINS OF QUARTZ, FELDSPAR, LITHIC FRAGMENTS AND MICA, TIGHTLY PACKED AND CEMENTED BY CALCITE AND CLAY, YELLOWISH GRAY.				77.8%	

ORY TESTING

ESULTS

F&E PART	L W PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
8"						
				NO EFFECT NO EFFECT	NO EFFECT NO EFFECT	RESISTANT
						DESPITE PO SERVICE RE HARDENS AN
						CA
						SU
						U. TO A

1 3

REMARKS
RESISTANT TO WEATHERING BUT EASILY BROKEN.
DESPITE POOR TEST RESULTS THIS MATERIAL HAS AN EXCELLENT SERVICE RECORD. THIS MATERIAL IS A CUT STONE THAT CASE-HARDENS AND BECOMES DURABLE.

CATTARAUGUS HARBOR, NEW YORK

OHIO MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY GDM, PHASE II

1 2

PLATE C29

SOURCE	FORMATION	PROPOSED USE	LAB NO.	
FRANCE STONE CO. QUARRY AT BELLEVUE. OH	COLUMBUS DOLOMITE LUCAS DOLOMITE		ORD 103/72.606C	DOLOMI
				DOLOMI ABSOR BROWN DOLOMI ABSOR
				DOLOMI ABSOR
FRANCE STONE CO. QUARRY AT BLOOMVILLE. OH	COLUMBUS DOLOMITE		ORD 103/73.606C	DOLOMI ABSOR DOLOMI ROUS,
				PALE Y DOLOM APPEA TURE,
FRANCE STONE COMPANY (FORMERLY NORTHERN OHIO STONE COMPANY) QUARRY AT FLAT ROCK, OH	LUCAS DOLOMITE		ORD 103/72.606C	DOLOM POROU ODOR, DOLOM UNSORT ISH O
				DOLOM WEATH

SUMMARY SHEET FOR LABORATOR

NO	PETROGRAPHIC ANALYSIS	TEST RESUL				
		SP.GRAV.	ABS.	$MgSO_4$	L.A.A	F&E
606C	DOLOMITE - 87% SANDY DOLOMITE - 12%, LAMINATED DOLOMITE - 1%.	2.58	3.39%	5%	27%	5%
	DOLOMITE - HARD, VERY FINE-GRAINED, VERY EVEN-TEXTURED, MICROPOROUS, ABSORBENT, SUB-CONCHOIDAL TO SUB-BLOCKY FRACTURE, MODERATELY YELLOWISH BROWN DOLOMITE - MODERATELY HARD, FINE-GRAINED, MICROPOROUS TO MACROPOROUS, ABSORBENT, IRREGULAR FRACTURE, MODERATELY YELLOWISH BROWN.	2.47 TO 2.58	2.86 TO 5.60%			
	DOLOMITE - MODERATELY HARD, FINE-GRAINED, BANDED, MICROPOROUS TO POROUS, ABSORBENT, IRREGULAR FRACTURE, MODERATE YELLOWISH BROWN.					
606C	DOLOMITE - MODERATELY HARD, FINE-GRAINED, EVEN-TEXTURED, MICROPOROUS, ABSORBENT, SUB-BLOCKY FRACTURE, YELLOWISH GRAY.	2.5	3.62%			
	DOLOMITE - MODERATELY HARD, VERY FINE-GRAINED, EVEN-TEXTURED, MICROPOROUS, ABSORBENT, TIGHT PAPER-THIN, SHALY BEDDING PLANES, BLOCKY FRACTURE PALE YELLOWISH BROWN.	2.62	2.32%			
	DOLOMITE - MODERATELY HARD, VERY FINE-GRAINED, VERY EVEN-TEXTURED, DENSE APPEARANCE BUT VERY MICROPOROUS, ABSORBENT, CHERT NODULES, BLOCKY FRACTURE, PALE YELLOWISH BROWN.	2.58	3.24%			
606C	DOLOMITE - MODERATELY HARD, FINE-GRAINED, EVEN-TEXTURED, DENSE TO MACROPOROUS, CLOSELY SPACED, PAPER-THIN CARBONACEOUS SEAMS, PETROLIFEROUS ODOR, GRAYISH ORANGE.	2.46	4.51%			
	DOLOMITIC LIMESTONE - HARD, FINE TO MEDIUM-GRAINED, MODERATELY DOLOMITIC, UNSORTED DOLOMITE RHOMBS AND FOSSIL DETRITUS IN A CALCEROUS MIX, GRAYISH ORANGE.	2.75	0.80%			
	DOLOMITIC LIMESTONE - 96%, LIMESTONE - 3%, SANDY DOLOMITIC LIMESTONE - 1% WEATHERED DOLOMITIC LIMESTONE - 1%.	(-3/4") 2.61 (1-1/2") 2.58	2.99% 3.34%	11% 15%	26% 42%	3%

ATORY TESTING

RESULTS

.A	F&E PART	L.W PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
	5%	NONE					3/4 T
					NO EFFECT NO EFFECT	CRACKING AND BREAKING DOWN OF SPECIMEN ON ONE SURFACE INTO 1" ANGULAR PARTICLES. SURFACE SPALLING.	LEDGE RIPRAP
						PARTIAL OPENING OF A THIN SHALY BEDDING SEAM.	FIVE SA
					NO EFFECT NO EFFECT	NO EFFECT NO EFFECT	
					NO EFFECT	NO EFFECT	
					NO EFFECT	SOME SURFACE SPALLING OVER ENTIRE SURFACE. PARTIAL OPENING OF VERY THIN SHALY BEDDING SEAM.	FIVE SA AND ABS
	3%	NONE NONE					TESTED

REMARKS
3/4 TO 1 1/2 INCH AGGREGATE.
LEDGE NO. 5 LOW SPECIFIC GRAVITY (2.22) NOT ACCEPTABLE FOR RIPRAP
FIVE SAMPLES TESTED.
FIVE SAMPLES TESTED. SPECIFIC GRAVITY RANGES FROM 2.46 TO 2.75 AND ABSORPTION RANGES FROM 0.80% TO 4.51%.
TESTED FOR CONCRETE AGGREGATES AND CELL FILL.

CATTARAUGUS HARBOR, NEW YORK

OHIO MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB N
E. KRAEMER AND SON, INC. QUARRY AT CLAY CENTER, OH.	NIAGARAN DOLOMITE		ORD 103/72.606
			ORD 103/72.606
NATIONAL LIME AND STONE CO. QUARRY AT CAREY, OH	NIAGARAN DOLOMITE		ORD 103/73.606C
NATIONAL LIME AND STONE COMPANY QUARRY AT MARION, OH	COLUMBUS DOLOMITE		ORD 103/73.606C

SUMMARY SHEET FOR LABORATOR

NO.	[illegible] ANALYSIS	SP GRAV	ABS	$MgSO_4$%	L.A.A.	FBE
[illegible]	[illegible] MODERATELY HARD TO HARD, FINE TO MEDIUM GRAINED, MEGAPOROUS TO [illegible] MEDIUM [illegible]	2.68 TO 2.72	0.60 TO 2.04			
[illegible]	[illegible] HARD [illegible] FILLED WITH CALCITE, [illegible]	C.A. [illegible] MAX 2.71	[illegible].9[illegible]	4	28	6
		F.A. 2.72	[illegible].65	9		6
[illegible]	[illegible] MODERATELY HARD [illegible]	[illegible] TO [illegible]	0.91 TO 5.98			
	[illegible] MODERATELY HARD [illegible] POROUS, ABSOR[illegible]					
	[illegible] MODERATELY HARD [illegible] POROUS, ABSORBENT, [illegible]					
[illegible]	[illegible] MODERATELY HARD [illegible] POROUS, ABSORBENT [illegible]	[illegible]	3.46%			
	[illegible] MODERATELY HARD [illegible] ABSORBENT [illegible]	[illegible]	2.83			

...TORY TESTING

...RESULTS							
	FINE PART	L W PART	SO PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
					NO EFFECT	NO EFFECT	
	6 ------------ 6	NONE	NONE	NONE			
							NOTE REL... STONE CO... CAPABLE ...
					ONE PARTIALLY OPENED FRACTURE.	NO EFFECT	
					NO EFFECT	NO EFFECT	

C...

SU...

...

TO...

REMARKS
OTE RELATIVELY LIGHT SPECIFIC GRAVITY. NATIONAL LIME AND TONE CO. WILL PRODUCE ONLY THEIR STANDARD PRODUCTION ITEMS. APABLE BUT RELUCTANT TO PRODUCE LARGE STONE SIZES.

CATTARAUGUS HARBOR, NEW YORK

OHIO MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

SOURCE	FORMATION	PROPOSED USE	LAB NO.
WOODVILLE LIME AND CHEMICAL CO. QUARRY AT WOODVILLE, OH	NIAGARAN DOLOMITE		ORD [illegible].320C
			ORD 101/7[illegible].3[illegible]2C
			ORD 101/7[illegible].3[illegible]2C
WYANDOT DOLOMITE, INC. QUARRY AT CAREY, OH	NIAGARAN DOLOMITE		ORD 103/73.606C

SUMMARY SHEET FOR LABORATO

AB NO.	TEST RES					
	PETROGRAPHIC ANALYSIS	SP GRAV.	ABS	$MgSO_4$	L.A.A.	F8
1.320C	DOLOMITE - MODERATELY HARD, FINE-GRAINED, MACROPOROUS, VUGGY, OLIVE GRAY TO LIGHT MEDIUM GRAY TO YELLOWISH GRAY; OCCASIONALLY IRON STAINED.	2.65	1.84%			
1.512C	DOLOMITE - HARD, MEDIUM-GRAINED, DENSE, POROUS, LIGHT GRAY TO LIGHT TAN.	2.68	2.1%	24.9%		20%
1.312C	DOLOMITE - MODERATELY HARD, FINE-GRAINED, POROUS TO VUGGY.	2.70	1.91%	24%		
					27.6%	
3.606C	DOLOMITE - MODERATELY HARD, FINE-GRAINED, SUGARY-TEXTURED, POROUS AND VUGGY, IRREGULAR FRACTURE, PALE OLIVE GRAY.	2.69	1.44%			
	DOLOMITE - MODERATELY HARD, MEDIUM-GRAINED, RUBBLY-TEXTURED, POROUS AND VUGGY, COQUINOID. IRREGULAR FRACTURE, PALE YELLOWISH BROWN.	2.65	1.60%			
	DOLOMITE (KLINTITE) MODERATELY HARD, FINE-GRAINED, RUBBLY TEXTURED, POROUS AND VUGGY. BRECCIATED APPEARANCE. IRREGULAR FRACTURE, YELLOWISH GRAY WITH MEDIUM GRAY MOTTLING.	NOTE: TEN SAMPLES WERE TESTED; SIX FROM THE UPP VARIED FROM 2.53 TO 2.70; ABSORPTION VARIED F 2.75. ABSORPTION VARIES FROM 0.55% TO 1.10%.				

ATORY TESTING

RESULTS							
A.A.	F & E PART	L W PART	SO. PART	CLAY LUMPS	WET-DRY (80 CYCLES)	FREEZE-THAW (35 CYCLES)	
					NO EFFECT	NO EFFECT	SAMPL FRACT CYCLE
	20%						TESTE FM=3.
							TESTE FM=3.
							TESTE FILTE
					NO EFFECT		
						NO EFFECT	
THE UPPER LIFT AND FOUR FROM THE LOWER LIFT. SPECIFIC GRAVITY FROM THE UPPER LIFT ARIED FROM 0.64% TO 2.11%. IN THE LOWER LIFT. SPECIFIC GRAVITY VARIES FROM 2.73 TO 1.10%. MANAGEMENT WILL PRODUCE ONLY CRUSHED STONE PRODUCTS.						NO EFFECT	T

REMARKS
SAMPLES CONTAINED SOME BLASTING FRACTURES. APPARENTLY THESE FRACTURES WERE NOT EFFECTED BY THE FREEZE-THAW, WET-DRY CYCLES.
TESTED FOR FINE AGGREGATE FOR CONCRETE (MANUFACTURED SAND: FM=3.03)
TESTED FOR FINE AGGREGATE FOR CONCRETE (MANUFACTURED SAND: FM=3.30)
TESTED FOR COARSE AGGREGATE FOR CONCRETE. GRANULAR BACKFILL. FILTER MATERIAL. BASE COURSE AND BEDDING.

CATTARAUGUS HARBOR, NEW YORK

OHIO MATERIAL SOURCES

SUMMARY OF LAB TEST RESULTS

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY GDM, PHASE II

APPENDIX D

DETAILED DESIGN

APPENDIX D
DETAILED DESIGN
FOR
CATTARAUGUS CREEK HARBOR,
NEW YORK

CONTENTS

CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

APPENDIX D
DETAILED DESIGN

INTRODUCTION

GENERAL

D1. This appendix presents the design criteria, assumptions and detailed design of the Cattaraugus Creek Harbor project features. The project features include two rubblemound breakwaters, a quarrystone-armored berm, a dredged channel with riprap section and two earth fills. The breakwater on the south side of Cattaraugus Creek is 1,850 feet long, and the breakwater on the north side of the creek is 600 feet long. The longer south breakwater is designed to have a massive concrete cap to enhance structural stability and to provide access for recreational fishing from the breakwater. The rubblemound breakwater was selected from a study of several alternative plans. The alternative plans included cellular steel and cantilever sheet-pile breakwaters, and rubblemound breakwaters using stone and concrete armor units. The Phase I General Design Memorandum included design of a comfort station, access road, and parking lot on the north side of the creek for recreational fishing benefits. The breakwaters have been realigned as a result of the hydraulic model studies. The entrance of the realigned plan faces north with the longer breakwater connected to the south side of the creek. A comfort station, parking lot, and access road are available on the south side of the creek and have, therefore, been deleted from the project plan. The project features presented in this appendix were designed in sufficient detail to develop a project cost estimate and provide a basis for final design.

WATER LEVELS

GENERAL

D2. Water levels on the Great Lakes vary from year to year and from month to month. Locally, water levels vary from day to day and from hour to hour. The seasonal variations usually consist of high levels in the summer and low levels in the winter. Yearly and seasonal fluctuations are caused by variations in precipitation rates within the Great Lakes Basin. Short-term fluctuations

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CATTARAUGUS CREEK HARBOR, NEW YORK GENERAL DESIGN MEMORANDUM. P--ETC(U)

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lasting from a few hours to several days are caused by meteorological disturbances. Differences in barometric pressures and winds blowing over the surface of the lake create temporary water fluctuations which vary locally. Astronomical tides are assumed to have a negligible influence on the water levels.

FLUCTUATIONS AND EXTREMES

D3. Continuous records of the water levels in Lake Erie have been monitored at Cleveland by the Lake Survey Centers since 1860. Table D1 summarizes the average extreme water levels as recorded by the Cleveland Water Level Gage. Lake Erie low water datum is 568.6 feet above International Great Lakes Datum, 1955 (IGLD), based on the mean low water level at Father Point, Quebec. The highest recorded monthly mean lake level was 573.5 feet in June, 1973, and the lowest was 567.5 feet in February, 1936, and in December, 1934 The highest annual average lake level was 572.7 feet in 1973 and the lowest was 568.1 feet in 1934. The average of the monthly mean lake levels for the period 1850 to 1974 was 570.4 feet. During the last five years, the annual maximum of the monthly means range from a low of 3.03 feet above low water datum in 1970 to the record high of 4.91 feet in 1973. The annual maximum of the monthly mean for the same period ranged from 1.89 feet above low water datum in 1969 to 3.17 feet above in 1973. The greatest annual fluctuation of the monthly mean lake level was 2.75 feet in 1947 and the least annual fluctuation was .87 feet in 1895. Similar fluctuations are assumed to occur during the life of the project.

DESIGN WATER LEVEL

D4. The Lake Survey Center maintains automatic water level gages in the vicinity of the project site at Buffalo, Barcelona, and Erie. Detroit District[1] has analyzed records from these gages and records from other gages to determine the 100-year open-coast flood levels. The maximum daily lake level distributions from these

---

[1]Great Lakes 100-Year Open-Coast Flood Levels, U. S. Army Corps of Engineers, Detroit, Michigan, Dec., 1974.

TABLE D1. Average and Extreme Water Levels

LAKE ERIE WATER LEVEL DATA

AT

CLEVELAND, OH

PERIOD 1860-1974

STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	1973	1973	1973	1973	1973	1973	1973	1973	1973	1973	1972	1972
HIGH	572.39	572.53	572.88	573.30	573.25	573.51	573.34	573.03	572.51	572.14	572.17	572.35
MEAN	569.912	569.874	570.092	570.627	570.957	571.110	571.070	570.880	570.597	570.267	570.006	569.944
	1935	1936	1934	1934	1934	1934	1934	1934	1934	1934	1934	1934
LOW	567.62	567.49	567.65	568.20	568.43	568.46	568.46	568.36	568.23	567.95	567.60	567.53
CHANGES	Jan-Feb	Feb-Mar	Mar-Apr	Apr-May	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep	Sep-Oct	Oct-Nov	Nov-Dec	Dec-Jan
	1952	1887	1913	1947	1892	1902	1915	1926	1926	1917	1927	1949-50
MAXIMUM RISE	+0.67	+0.78	+1.57	+0.95	+0.76	+0.63	+0.26	+0.13	+0.28	+0.14	+0.52	+0.78
AVERAGE	-0.040	+0.218	+0.535	+0.329	+0.154	-0.037	-0.190	-0.283	-0.330	-0.261	-0.063	-0.029
	1886	1931	1891	1891	1930	1890	1868	1937	1871	1924	1882	1917-18
MAXIMUM FALL	-0.73	-0.31	-0.13	-0.18	-0.21	-0.38	-0.52	-0.57	-0.67	-0.64	-0.51	-0.67

Ave. 1860-1975 570.445
Ave. 1900-1974 570.257

LWD 568.6

January 1975

gages are plotted in Figure D1 for Buffalo, Barcelona, and Erie. Cattaraugus lies between Buffalo and Barcelona. The Cattaraugus lake level distribution was interpolated and is shown plotted in Figure D1. The 100-year recurrence water level at Cattaraugus was taken from Reference 1. The apparent inconsistent trend of distributions between the Erie and Barcelona gages is attributed in part to the data set. The Buffalo gage has 74 years of record, whereas Barcelona and Erie have 13 and 15 years, respectively. The 20-year recurrence water level at Cattaraugus is +8 feet LWD.

D5. The design lake level is a combination of the joint occurrence of long-term average lake level with short-term rise due to a storm setup. Figure D2 shows a short-term wind setup[2] for Buffalo. The high setups are due primarily to southwesterly winds. The wind setup distribution along the major axis of Lake Erie is shown in Figure D3 for a specific storm of March, 1955.[3] The setup at Cattaraugus is approximately 80 percent of that at Buffalo. The short-term setup distribution at Cattaraugus is plotted in Figure D1 by applying a 20 percent reduction to the Buffalo setup distribution in Figure D2. This assumption is valid for southwesterly winds from which the high setups are induced; however, it is not necessarily valid for the shorter recurrence intervals with winds from a northerly direction. The 20-year recurrence water level may then be determined by combination of a long-term lake level with a short-term rise. A 3.4-foot monthly mean lake level occurs approximately once in 20 years. The annual average lake level is +1.8 feet. This curve is plotted in Figure D1. Various combinations of the short- and long-term water levels can yield a water level for a given recurrence interval. Combining a 3.4-foot monthly mean lake level with a 20-year recurrence with a 4-foot setup with a 1-year recurrence yields a 7.4-foot, 20-year recurrence lake level. This is approximately ½-foot lower than the level obtained from the open-coast flood level. The 7.4-foot level was derived using a low recurrence period, short-term setup. Other combinations

[2]Saville, T., Wave and Lake Level Statistics for Lake Erie, U.S. Army Corps of Engineers, Technical Memorandum No. 37, March, 1953.

[3]Shore Protection Manual, U.S. Army Coastal Engineering Research Center, 1973.

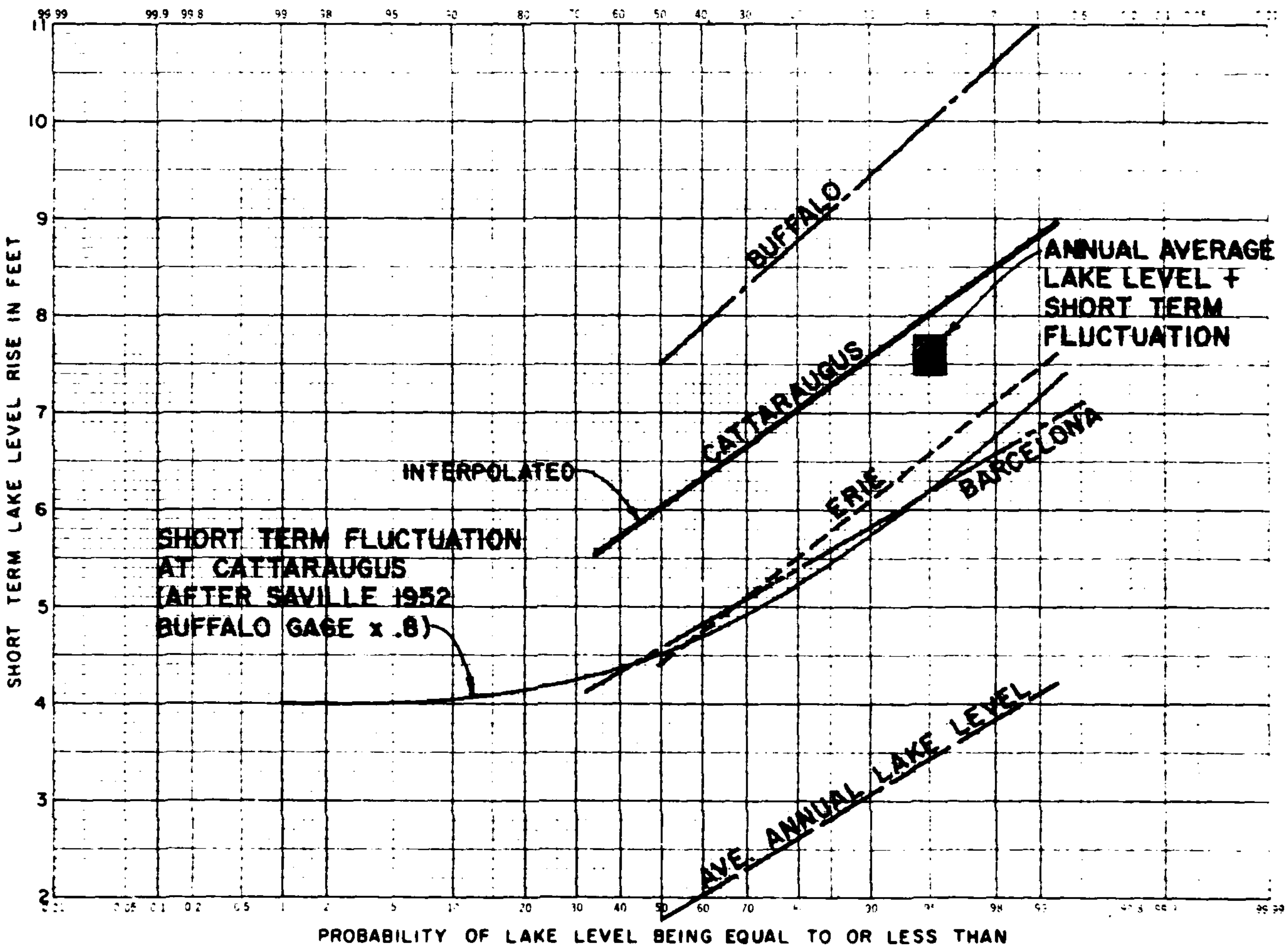
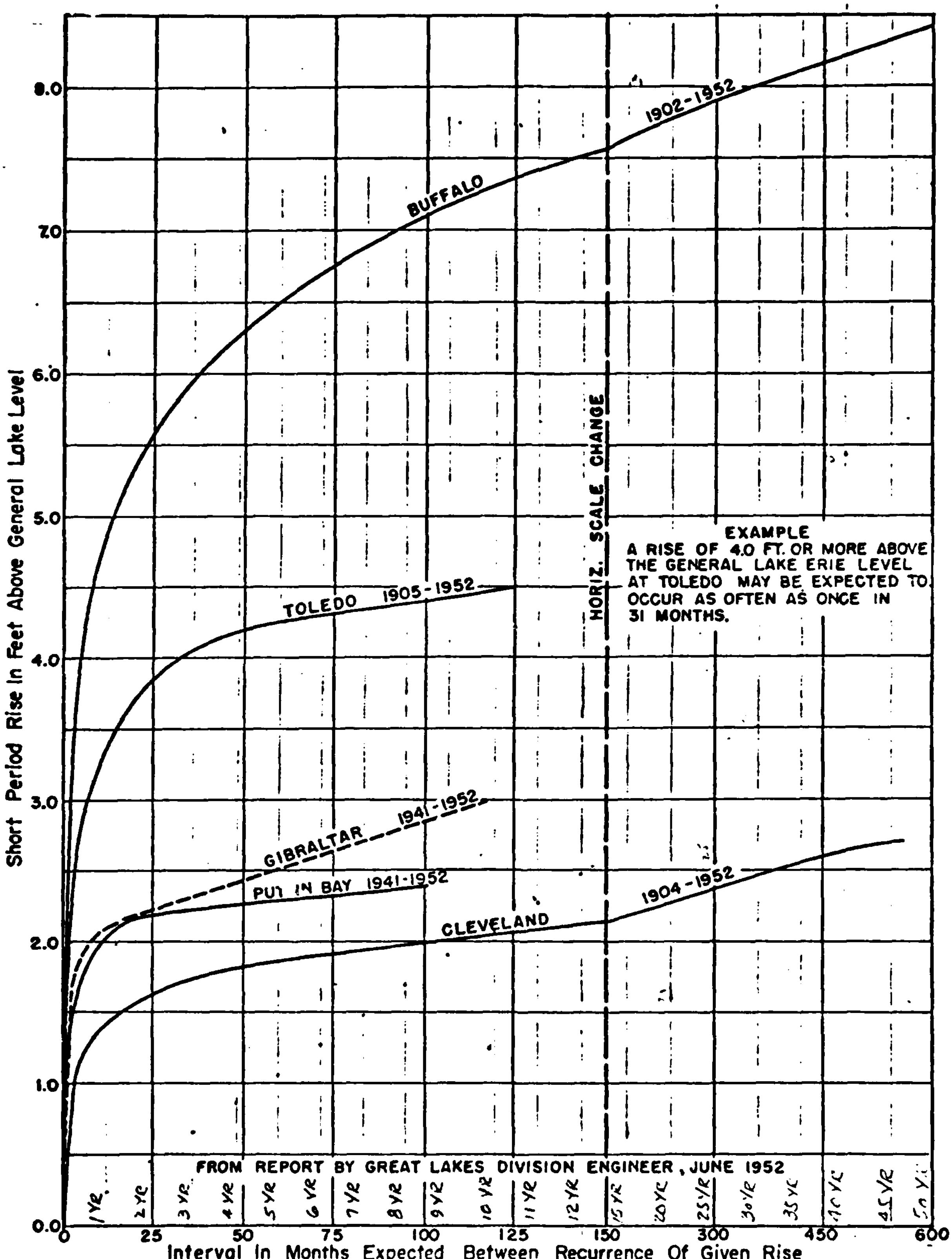


FIGURE [illegible]. CATTARAUGUS LAKE LEVEL DISTRIBUTION



FREQUENCY OF OCCURRENCE SHORT PERIOD FLUCTUATIONS
LAKE ERIE

FIGURE D2.

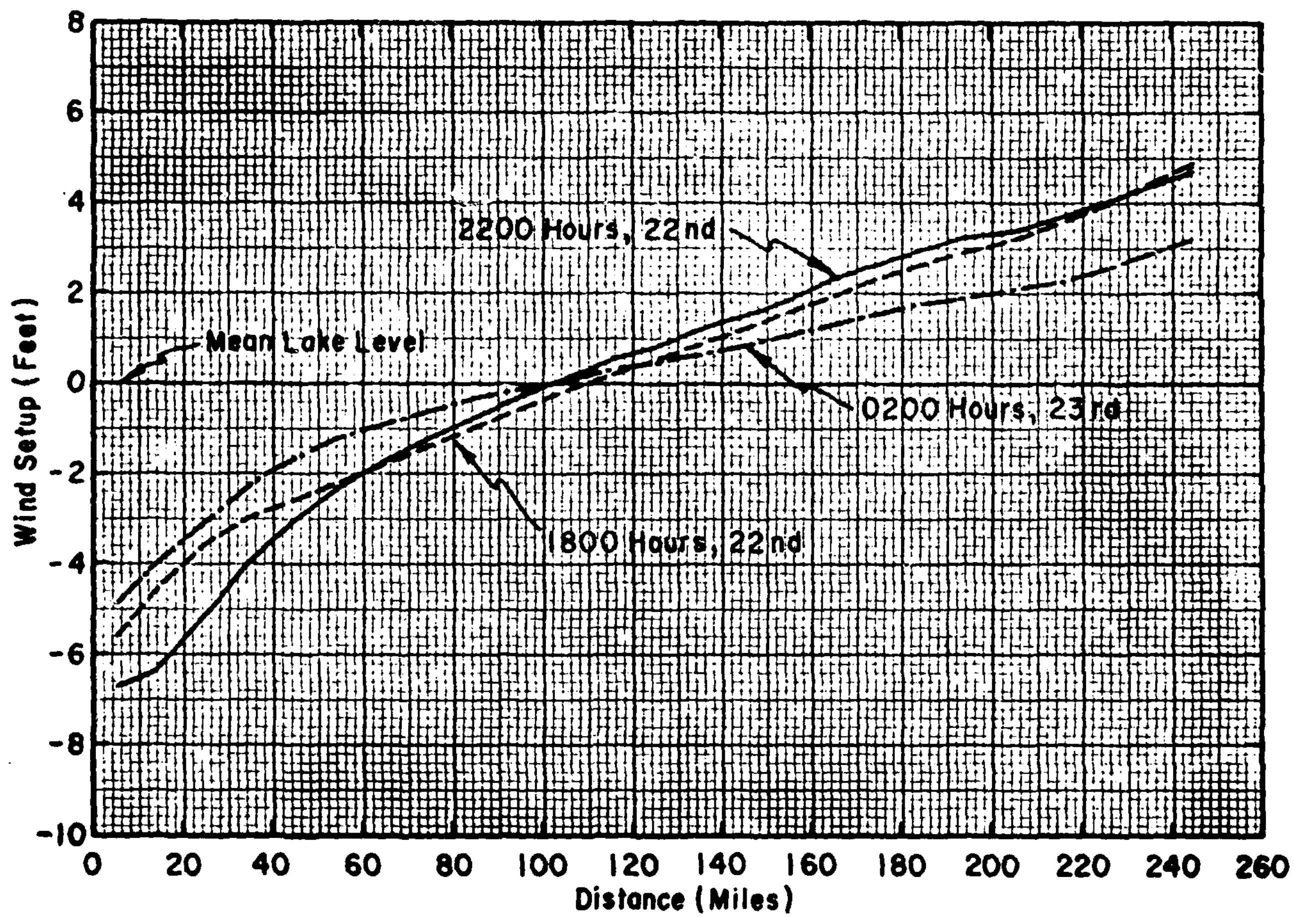


FIGURE D3. **Wind Setup Profile for Lake Erie. Storm, March 1955.**

of long- and short-term fluctuations yield 20-year recurrence levels up to 7.8 feet. This range of levels is plotted in Figure D1. An 8-foot design water level which corresponds to the 20-year open-coast flood level was selected for design.

D6. The model study[4] report used a 1-year recurrence water level of 6.8 feet comprising a 1.8-foot average annual water level with a 5-foot setup with a 1-year recurrence. The Phase I General Design Memorandum report used a 1.8-foot annual average with a 1.2-foot setup with a once-per-month recurrence. This yielded a once-per-month recurrence. The 8-foot design water level selected for the 20-year recurrence interval has a significant influence upon the design of shore structures.

DESIGN WAVES

INCIDENT WAVES

D7. Cattaraugus Creek is exposed to waves approaching from southwest clockwise through northeast. The fetch lengths are over 100 miles from the southwest and west-southwest and are less than 15 miles from the northeast. W.E.S. developed design waves by a computer hindcast using a modified N.Y.U. hindcast model. Twenty-six years of wind data from Buffalo were used in the hindcast. A factor of 1.1 was used to multiply all winds to correct for over-water wind speeds before they were input into the wave model, even though recent studies showed that this factor should be approximately 1.0 for high wind speeds. Figure D4 shows the mean recurrence intervals for significant wave heights in Cattaraugus Creek as a function of the direction. Table D2 gives the significant period associated with each wave height as a function of wave direction. Figure D5 is a plot of wave height versus wave period as a function of deep-water direction.

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[4] Design for Wave Protection Flood Control in Prevention of Shoaling in Cattaraugus Creek Harbor, New York, Bottin, R.R., and Chatham, Waterways Experiment Station, Draft Report. Appendix A.

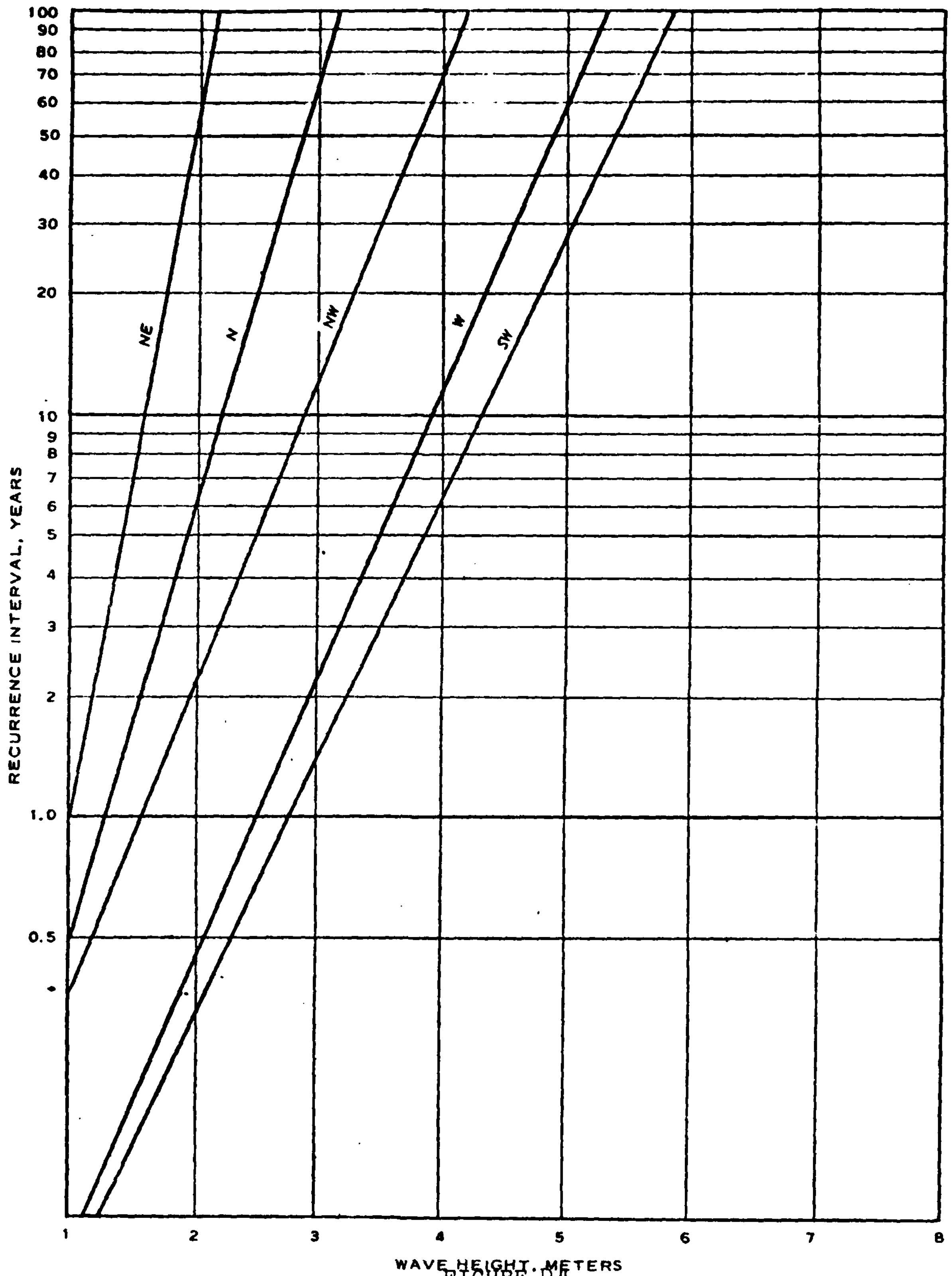


FIGURE D4
MEAN RECURRENCE INTERVALS FOR SIGNIFICANT WAVE HEIGHTS AT CATTARAUGUS CREEK

TABLE D2.

SIGNIFICANT PERIODS ASSOCIATED WITH

WAVES AT CATTARAUGUS

Approach Direction	Wave Height, Meters					
	1	2	3	4	5	6
NE	5.4	6.5				
N	5.4	6.6				
NW	5.5	6.8	7.5			
W	5.6	6.9	7.7	9.0	10.0	
SW	5.8	7.2	8.1	9.6	10.5	11.1

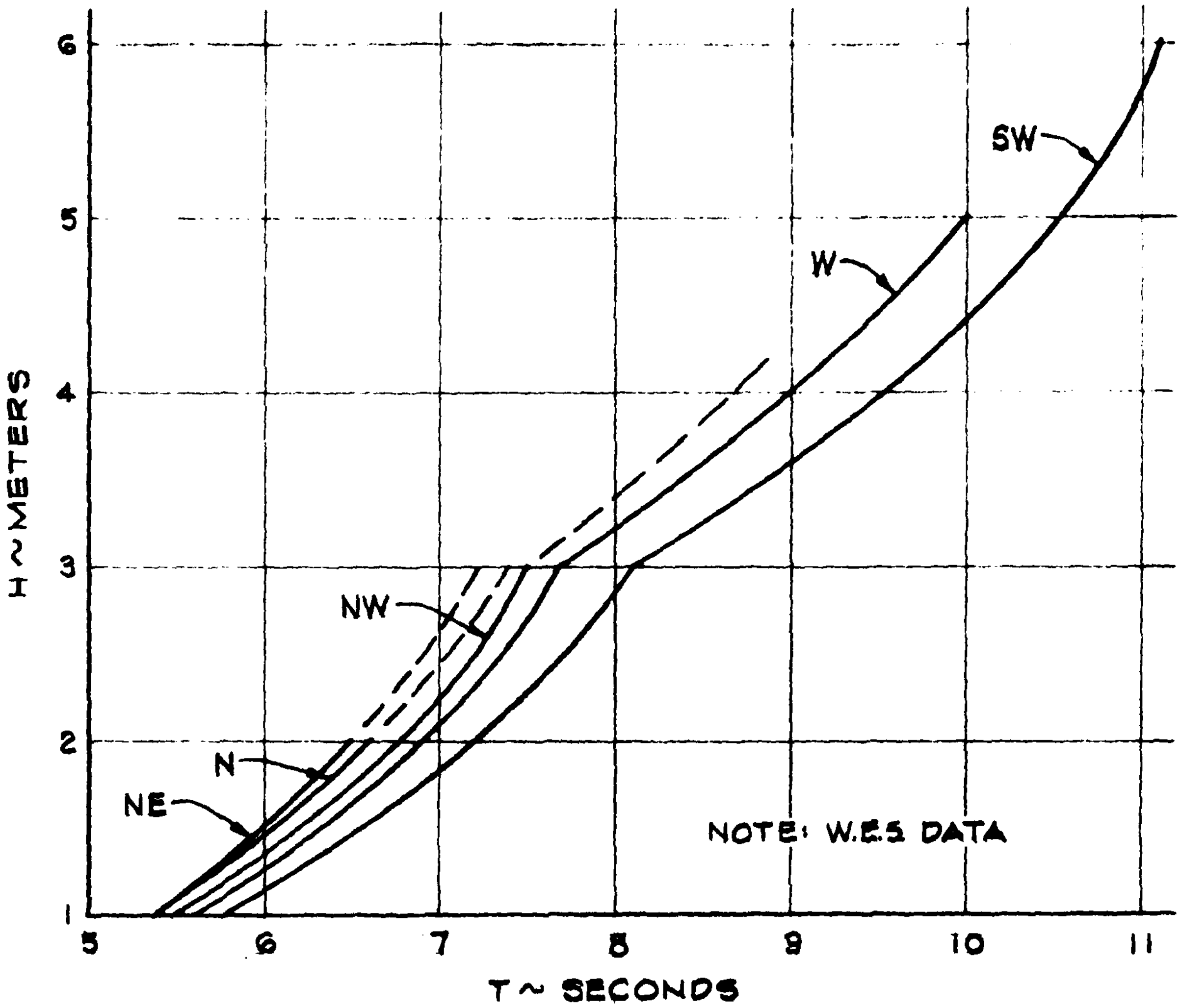


FIGURE D.5
WAVE PERIOD VS. WAVE HEIGHT

REFRACTION ANALYSIS

D8. Refraction analyses were conducted to transform the hindcast deep-water waves to equivalent deep-water wave heights at the breakwater location. A preliminary model was used assuming straight and parallel bottom contours representative of the generating area to transform the waves to the 60-foot depth and 50-foot depth for the southwest to north and north-northeast to northeast directions, respectively. The analysis is given in Table D3. The results indicate that the northeast and southwest waves are oriented parallel to the bottom contours and, consequently, refract to shore with a refraction coefficient of zero. Since waves from these directions may have a controlling influence on the design, wave heights were interpolated for directions 22.5° toward the west in both cases. This yielded 20-year recurrence waves from less oblique angles of attack. Table D4 lists five design deep-water waves used in the detailed refraction analysis. The refraction diagrams for the five 20-year recurrence design waves are given as Figures D6 through D10. The refraction coefficients and orthogonal azimuths taken at the 10-foot depth contour are listed in Table D4. The equivalent deep-water wave height at the breakwater is given by H_{os}'. The maximum design wave height is $H_o' = 11.1$ feet from the northwest, with $T = 7.8$ seconds. The higher deep-water waves from the more westerly directions are refracted more and have lower refraction coefficients. The bathymetry to the southwest of the project site locally causes a caustic to form over a ridge. The formation of the ridge causes a localized divergence on either side. The ridge did not cause a convergence in the vicinity of the breakwater.

D9. The south breakwater affords protection to the north breakwater from direct wave attack. The diffraction diagrams for the design waves are given in Figures D11 through D15. Diffraction coefficients and the design equivalent deep-water waves are summarized in Table D5.

TABLE D3

PRELIMINARY REFRACTION ANALYSIS - DESIGN WAVES

Dir.	Az.	α_1	d	T	d_1/L_o	$Tanh d_1 k_1$	d_2/L_o	$Tanh d_2 k_1$	C_2/C_1	α_1	Az.	K_r
SW	22.5	90.0	108	10.3	.199	.888	.125	.770	.867	60	255.0	0.00
WSW*	247.5	67.5	108	9.8	.220	.909	.138	.800	.880	54	261.0	.90
W	270.0	45.0	108	9.3	.244	.929	.153	.823	.886	39	276.0	.98
NW	315.0	0.0	80	7.8	.257	.938	.218	.907	.967	0	315.0	1.00
N	360.0	50.0	80	7.0	.319	.969	.271	.947	.977	48	358.0	.99
NNE*	22.5	70.0	63	6.7	.274	.938	.231	.896	.955	64	16.5	.94
NE	45.0	90.0	68	6.3	.335	.974	.335	.974	1.000	90	45.0	0.00

TABLE D4

REFRACTION ANALYSIS

Direction	Az_o	T	H_o	Kr_1	$H_o'd$	Az_{60}	Kr_2	$H_o's$	Az_{10}
WSW	247.5	9.8	15.0	.90	13.5	261.0	.67	9.05	293.0
W	270.0	9.3	14.2	.98	13.9	276.0	.67	9.32	296.0
NW	315.0	7.8	10.8	1.00	10.8	315.0	1.03	11.12	310.0
N	0.0	7.0	8.1	.99	8.0	358.0	.79	6.34	330.0
NNE*	22.5	6.7	7.0	.94	6.6	16.5	.32	2.11	328.0

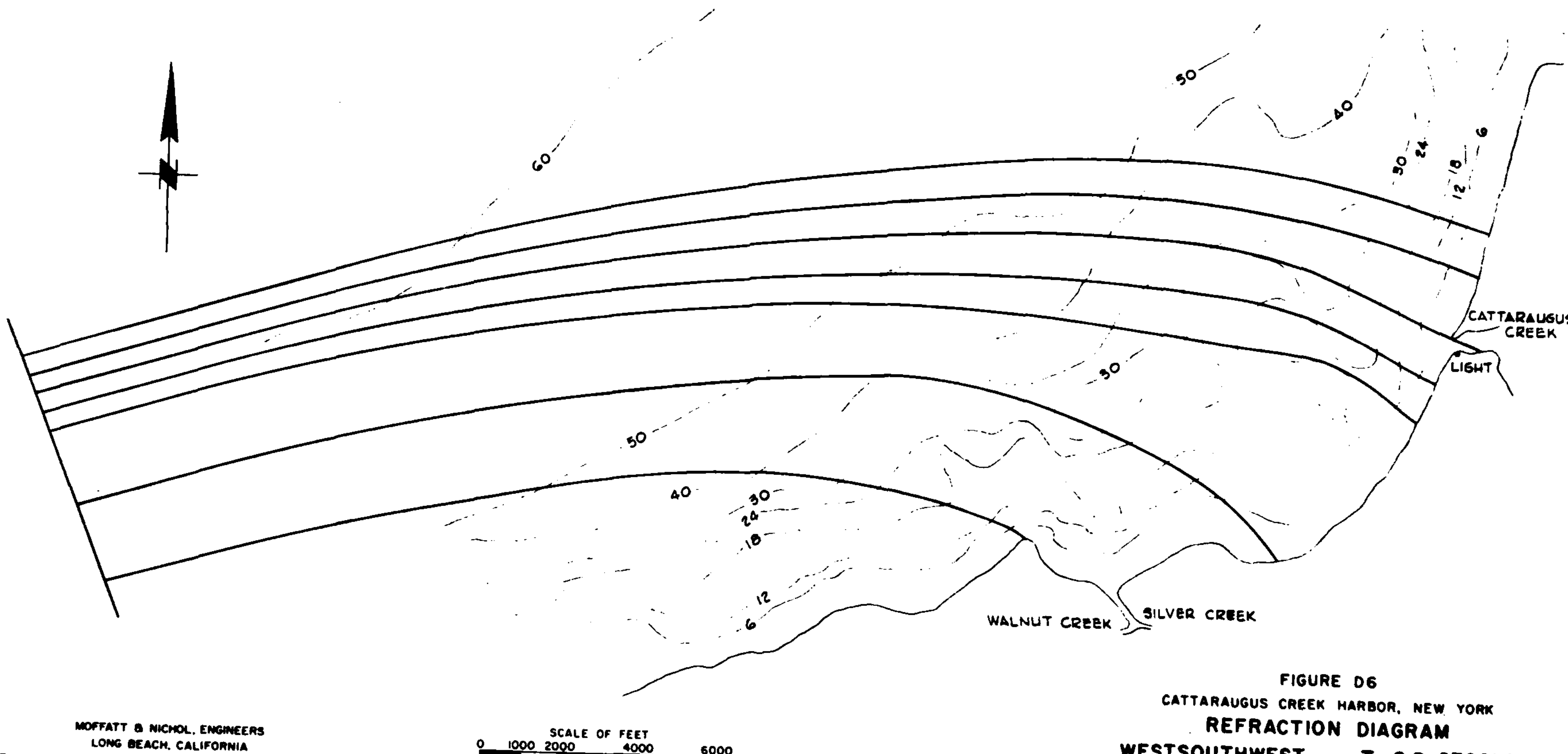


FIGURE D6

CATTARAUGUS CREEK HARBOR, NEW YORK

REFRACTION DIAGRAM

WESTSOUTHWEST T = 9.8 SECONDS

MOFFATT & NICHOL, ENGINEERS
LONG BEACH, CALIFORNIA

D15

D15

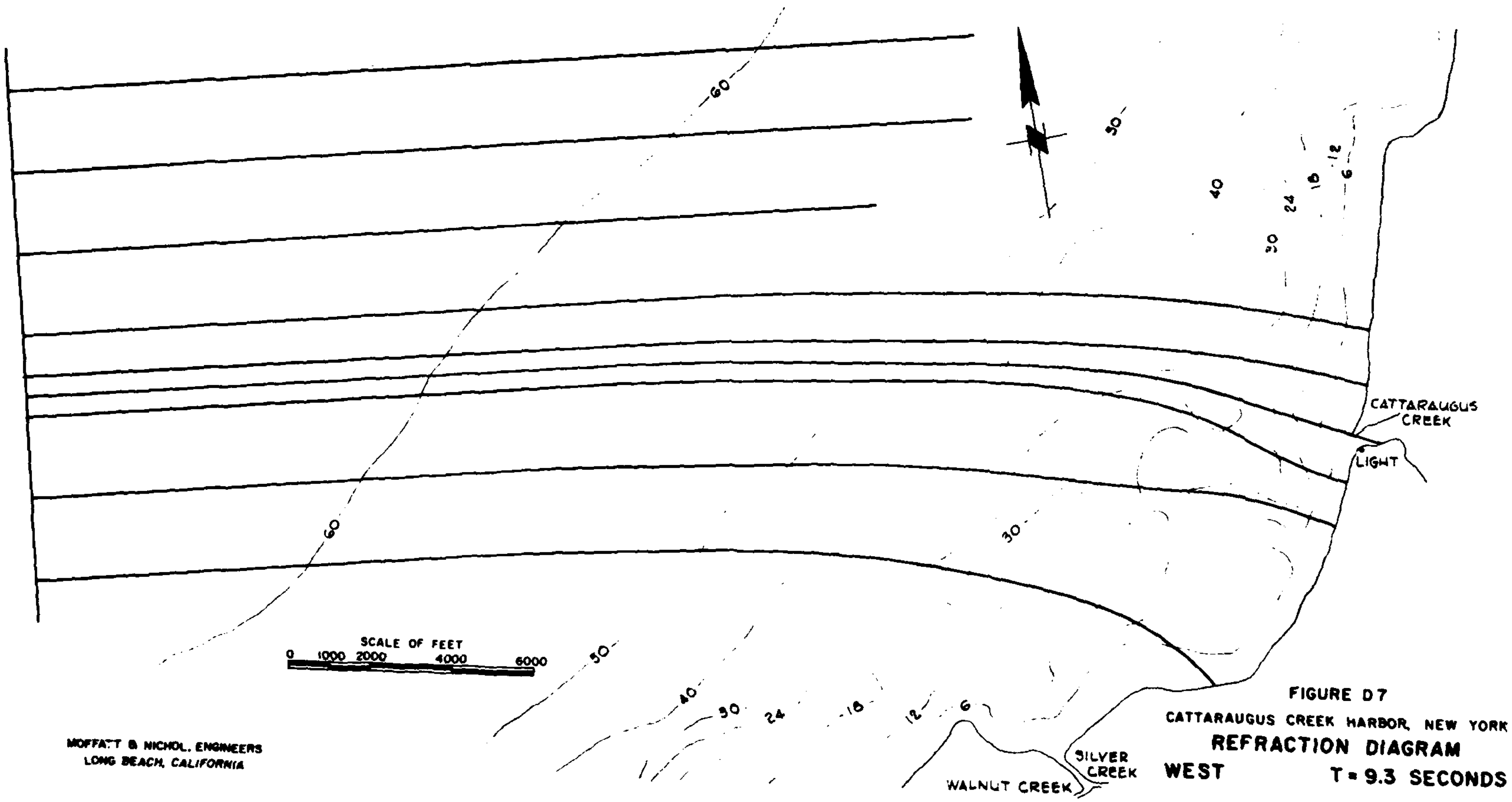


FIGURE D7
CATTARAUGUS CREEK HARBOR, NEW YORK
REFRACTION DIAGRAM
WEST T = 9.3 SECONDS

MOFFATT & NICHOL, ENGINEERS
LONG BEACH, CALIFORNIA

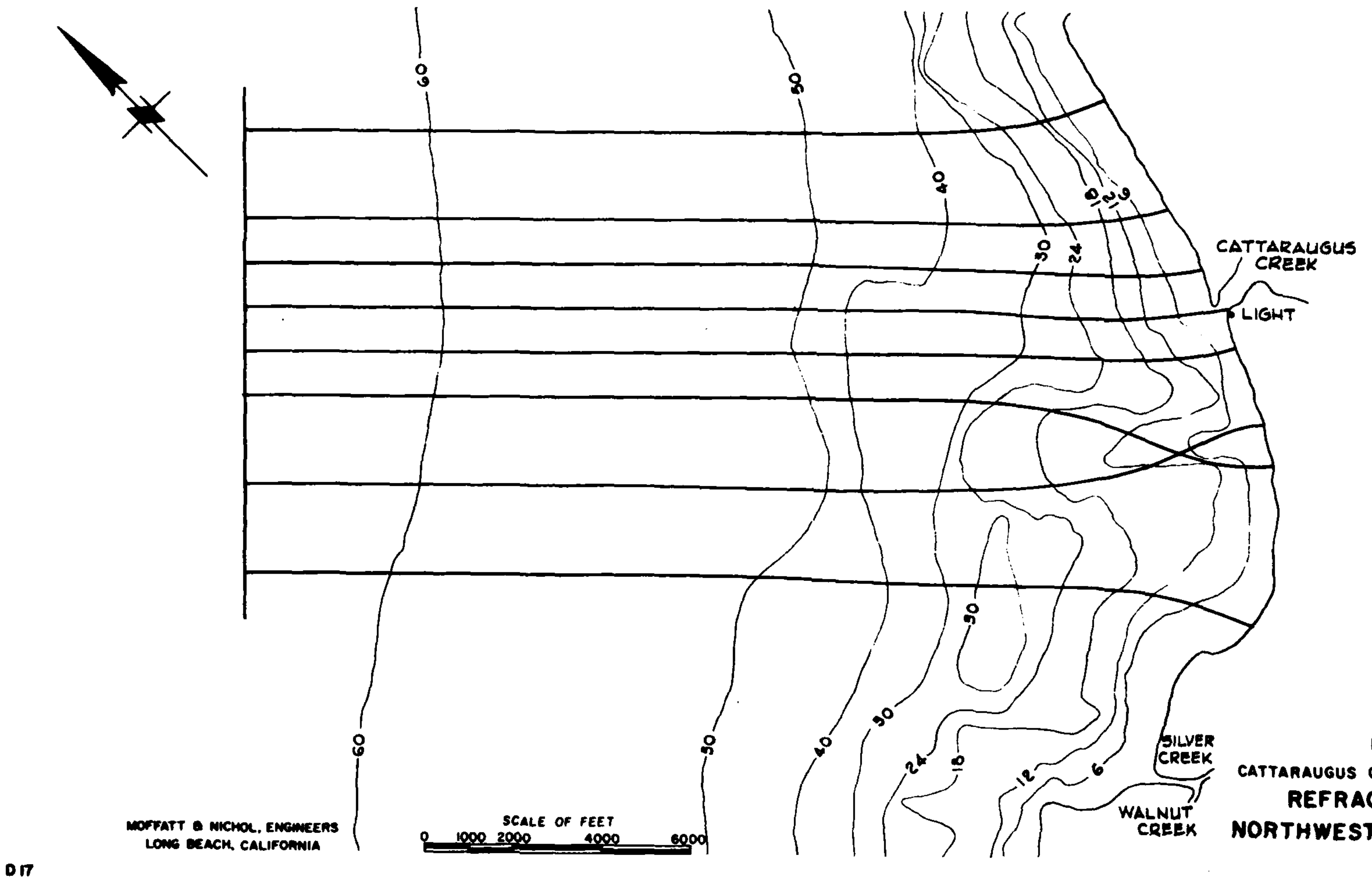


FIGURE D8
CATTARAUGUS CREEK HARBOR, NEW YORK
REFRACTION DIAGRAM
NORTHWEST T = 7.8 SECONDS

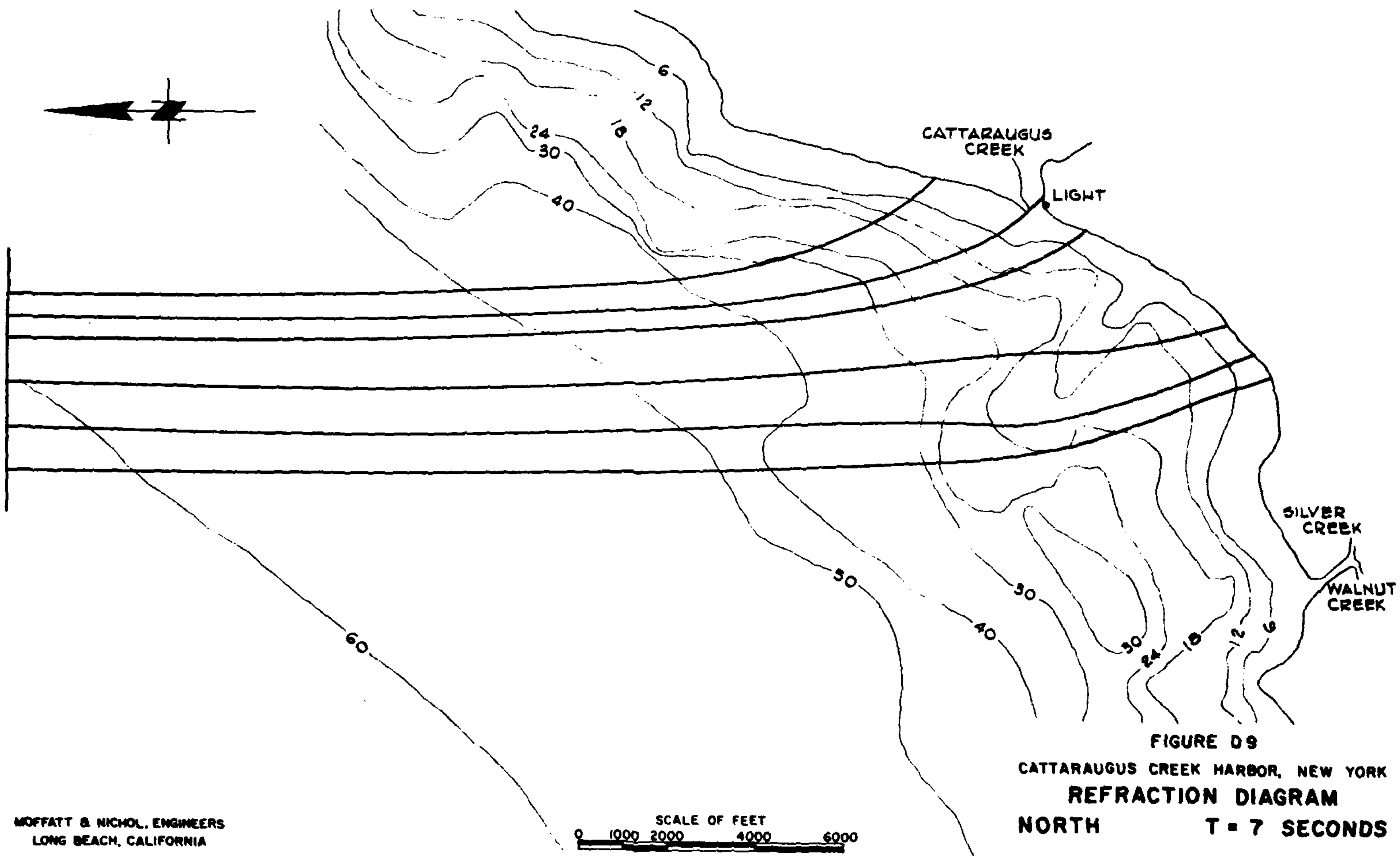


FIGURE D9
CATTARAUGUS CREEK HARBOR, NEW YORK
REFRACTION DIAGRAM
NORTH T = 7 SECONDS

MOFFATT & NICHOL, ENGINEERS
LONG BEACH, CALIFORNIA

D18

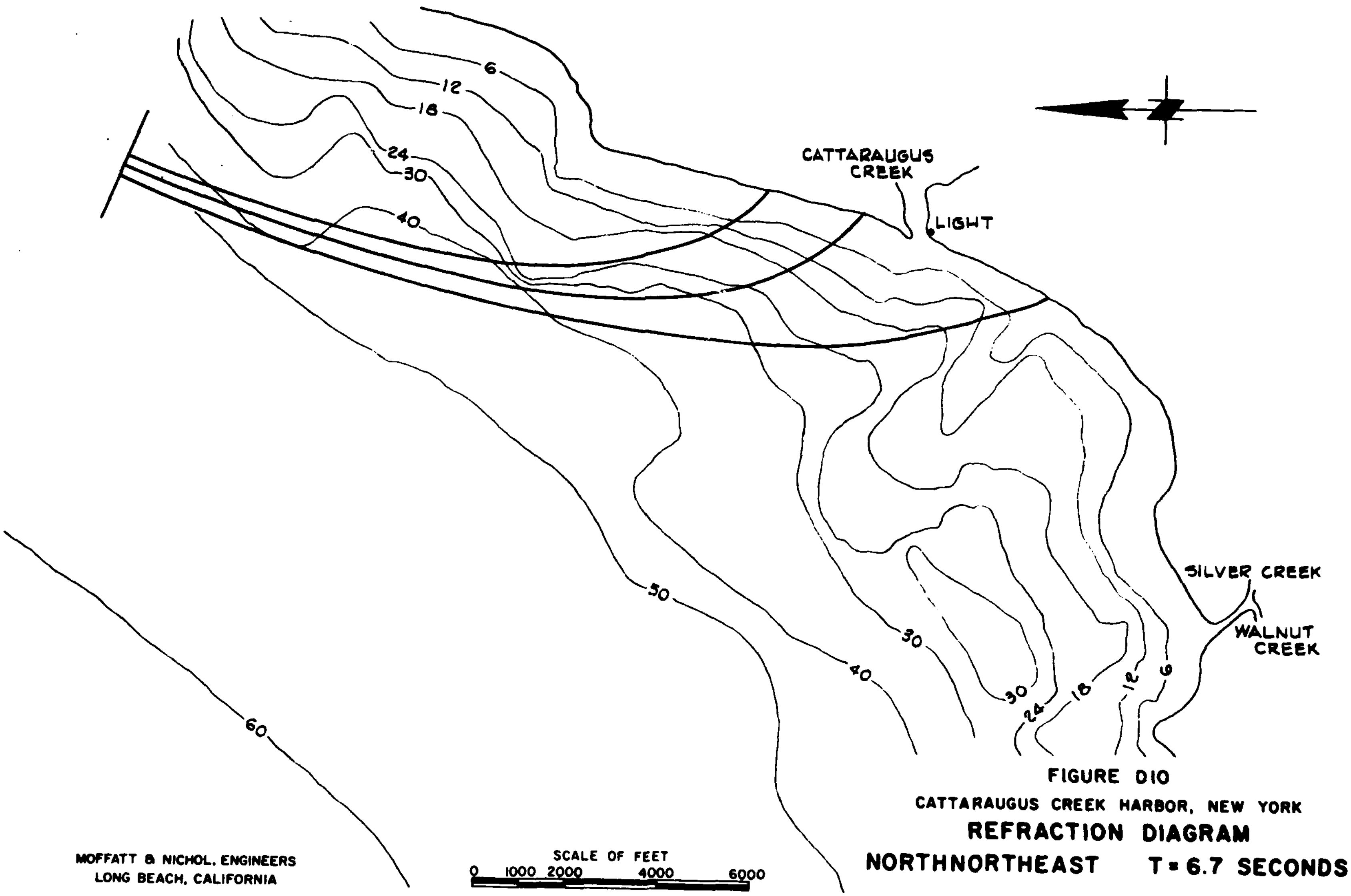


FIGURE D10

CATTARAUGUS CREEK HARBOR, NEW YORK

REFRACTION DIAGRAM

NORTHNORTHEAST T = 6.7 SECONDS

MOFFATT & NICHOL, ENGINEERS
LONG BEACH, CALIFORNIA

D19

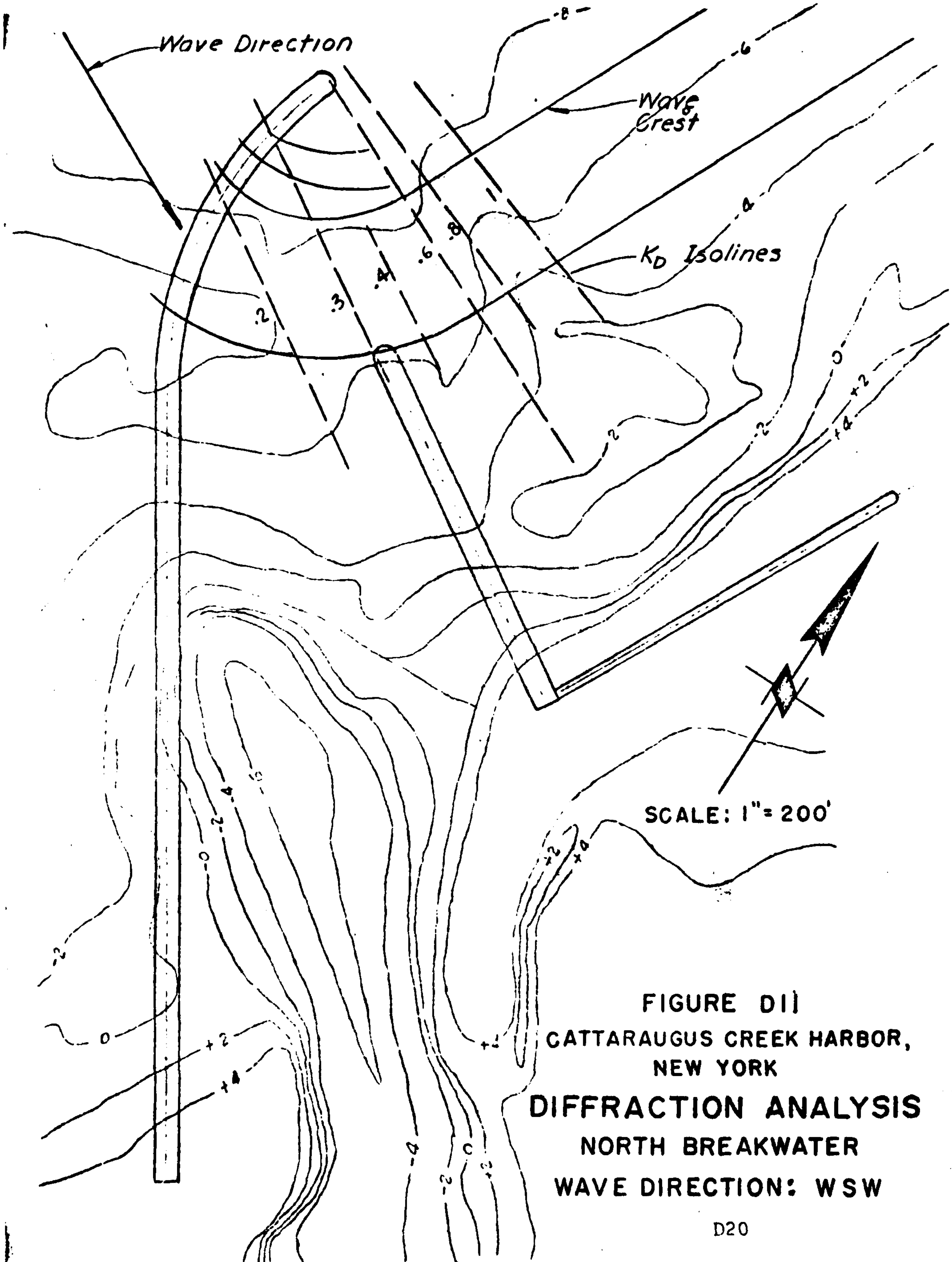


FIGURE D11
CATTARAUGUS CREEK HARBOR, NEW YORK
DIFFRACTION ANALYSIS
NORTH BREAKWATER
WAVE DIRECTION: WSW

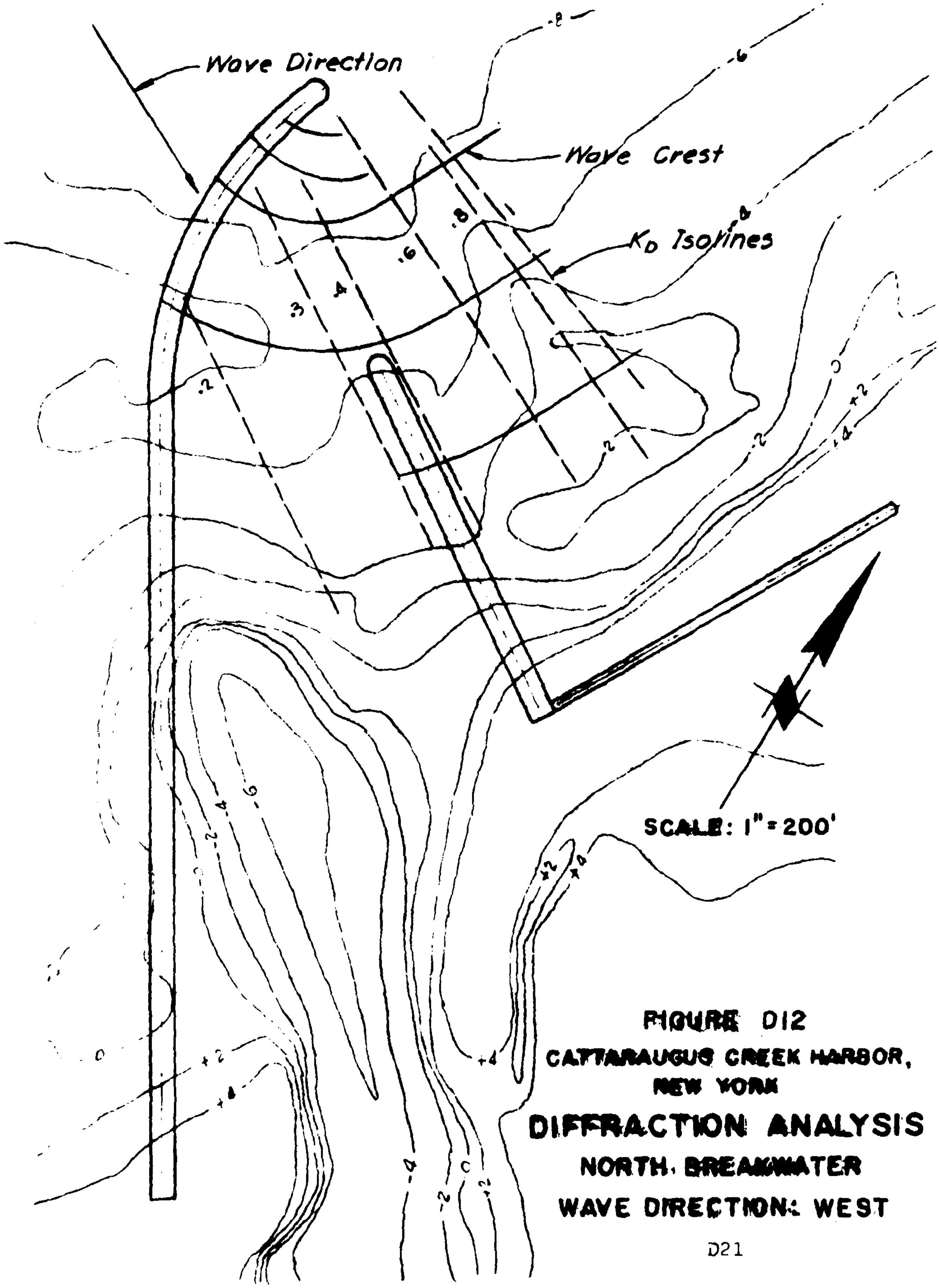


FIGURE D12
CATTARAUGUS CREEK HARBOR,
NEW YORK
DIFFRACTION ANALYSIS
NORTH BREAKWATER
WAVE DIRECTION: WEST

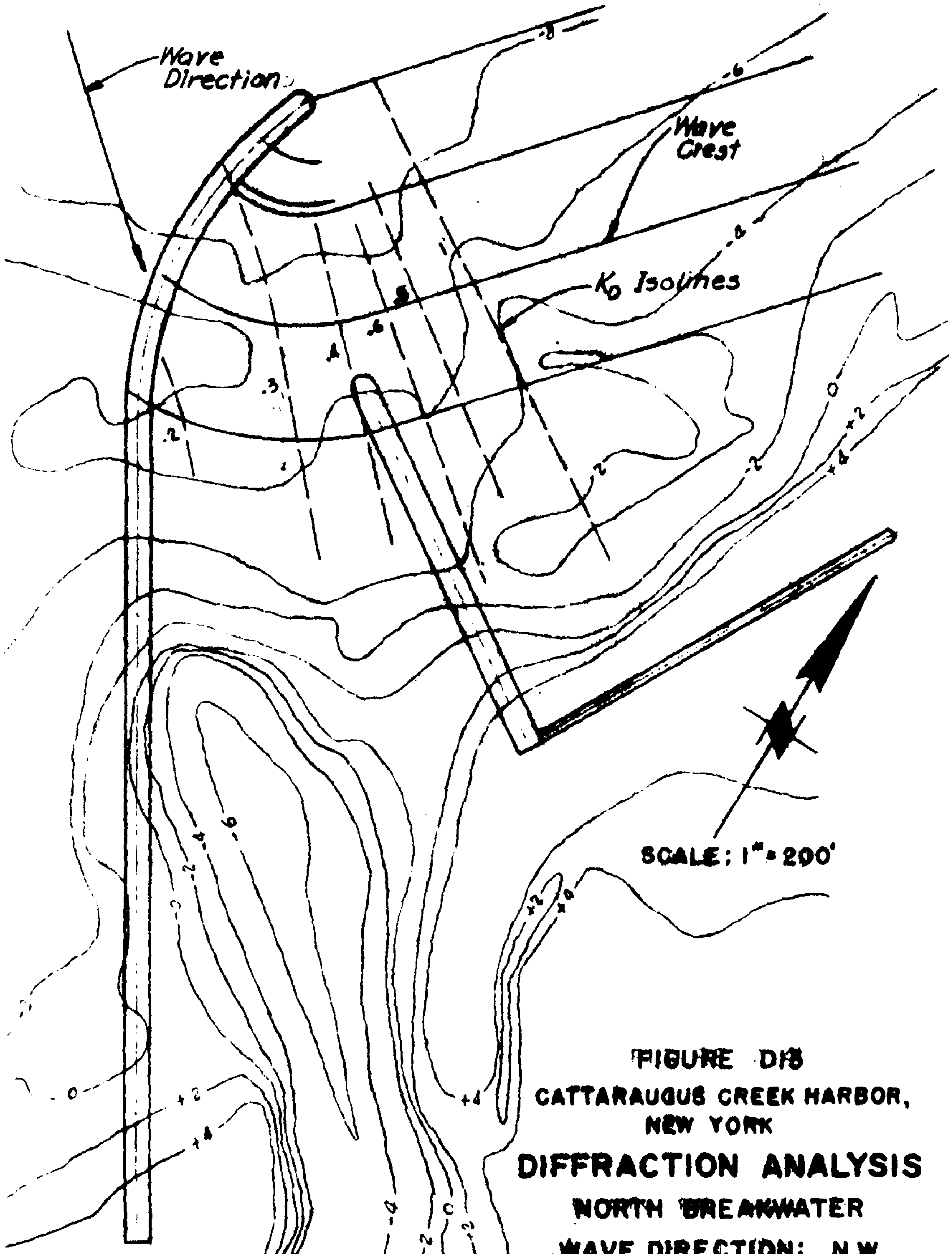


FIGURE D18
CATTARAUGUS CREEK HARBOR, NEW YORK
DIFFRACTION ANALYSIS
NORTH BREAKWATER
WAVE DIRECTION: N W

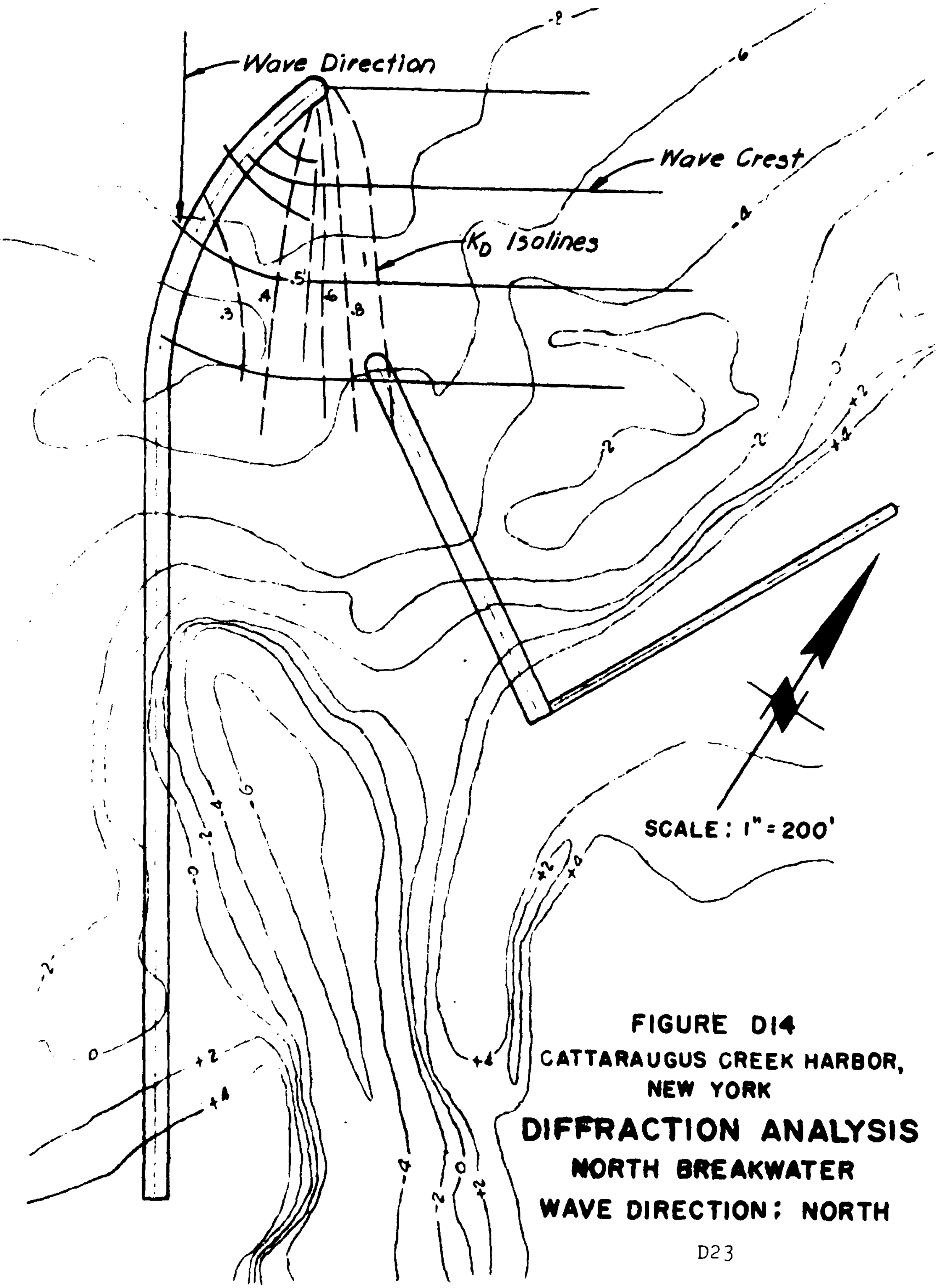


FIGURE D14
CATTARAUGUS CREEK HARBOR,
NEW YORK

DIFFRACTION ANALYSIS
NORTH BREAKWATER
WAVE DIRECTION; NORTH

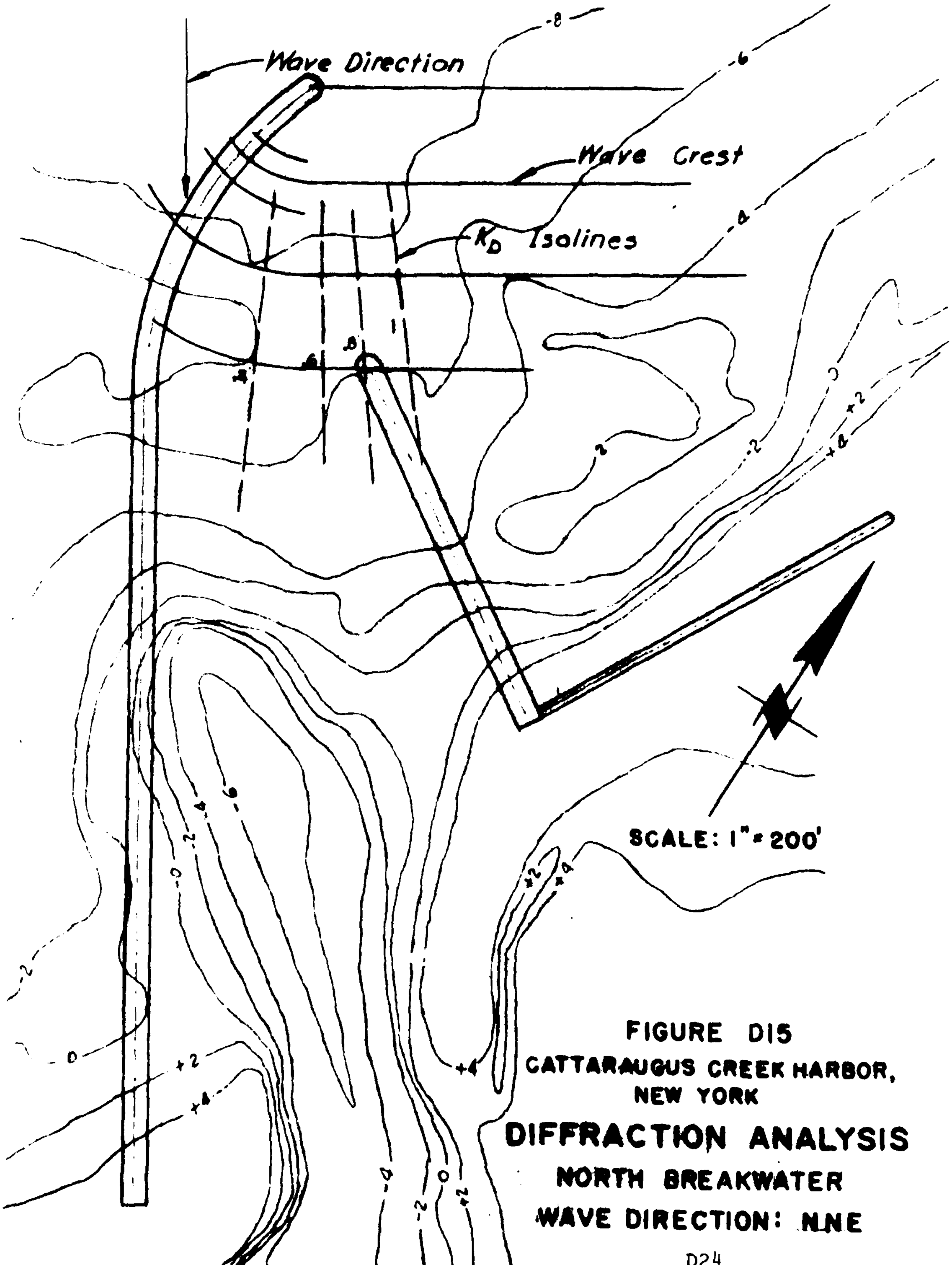


FIGURE D15
CATTARAUGUS CREEK HARBOR, NEW YORK
DIFFRACTION ANALYSIS
NORTH BREAKWATER
WAVE DIRECTION: NNE

TABLE D5

DIFFRACTION ANALYSIS

Direction	H_o'	T	K_d (Head)	K_d (Trunk)	H_o' (Head)	H_{os}' (Trunk)
WSW	9.05	9.8	.35	.35	3.2	3.2
W	9.32	9.3	.40	.40	3.7	3.7
NW	11.12	7.8	.45	.60	5.0	6.7
N	6.34	7.0	.80	1.00	5.0	6.3
NNE	2.10	6.7	1.00	1.00	2.1	2.1

BREAKWATERS

DESIGN CRITERIA AND ASSUMPTIONS

D10. The primary purposes of the project are to provide flood control, navigation, and recreational fishing benefits. The breakwaters were designed primarily to maintain Cattaraugus Creek free from littoral drift which presently develops into a bar or shoal in the mouth of the creek. Ice forms on the bar in the winter creating a barrier that increases backwater effects during floods. The breakwaters must therefore provide a relatively impermeable barrier that prohibits littoral drift from entering the channel from adjacent beaches to the north and the south. The breakwater plan-configuration was designed to allow ice to pass freely from the river into the lake. The breakwaters were also designed to provide a safe navigation entrance channel and to provide adequate protection against waves entering the mooring area. Criteria specify a maximum 2.5-foot wave height at the creek mouth and a .5-foot wave height in the mooring area for a 20-year recurrence period. The breakwaters were designed using a 20-year recurrence lake level of +8 feet LWD and to be stable for a 20-year recurrence significant wave height of 11.7 feet. A walkway and handrail were designed for the south breakwater to provide recreational fishing benefits. The project features were designed for a 50-year project life. An interest rate of 3¼%, which was effective during project authorization, was used to determine the annual costs. The design was based on using stone having a density of 165 pounds per cubic foot and concrete having a density of 144 pounds per cubic foot. Soils were assumed to have properties described in Appendix C, Geology, Soils, and Construction Materials.

ALIGNMENT

D11. The breakwater alignment was based upon the alignment recommended in Appendix A. The alignments and stationing are shown in Figure D16. The two breakwaters were aligned to maintain a navigation channel oriented in a northwesterly direction. The south breakwater was aligned to prevent littoral drift from forming a shoal in the mouth of Cattaraugus Creek during episodes of southwesterly wave attack and to reduce wave heights in the navigation channel and mooring areas. The north breakwater was designed to prevent littoral drift from forming a shoal in the creek mouth during episodes of northerly wave attack. The breakwater alignment basically follows Plan 8 of the hydraulic model study. The alignment was designed to introduce fluvial sediment transport into the north beach littoral zone and to bypass sediment from the southern beaches around the breakwater and channel. The alignment of the south breakwater was modified from that tested in the model study. The breakwater tested in the model study had a dogleg configuration. The rounded breakwater, shown in Figure D1, forms a more efficient hydraulic channel that should result in less hydraulic resistance than the tested dogleg alignment. The rounded section is also approximately 60 feet shorter than the dogleg section, resulting in a significant cost savings.

DESIGN PROFILES

D12. The south breakwater is 1,850 feet long. The breakwater is rooted into a high sand dune at Elevation +12 feet LWD and extends into the lake on an azimuth of 330 degrees to a depth of -9 feet LWD. A profile taken through the centerline of the breakwater is presented in Figure D17. The 1974 lake soundings indicate the presence of a sand bar off the creek mouth. The break-

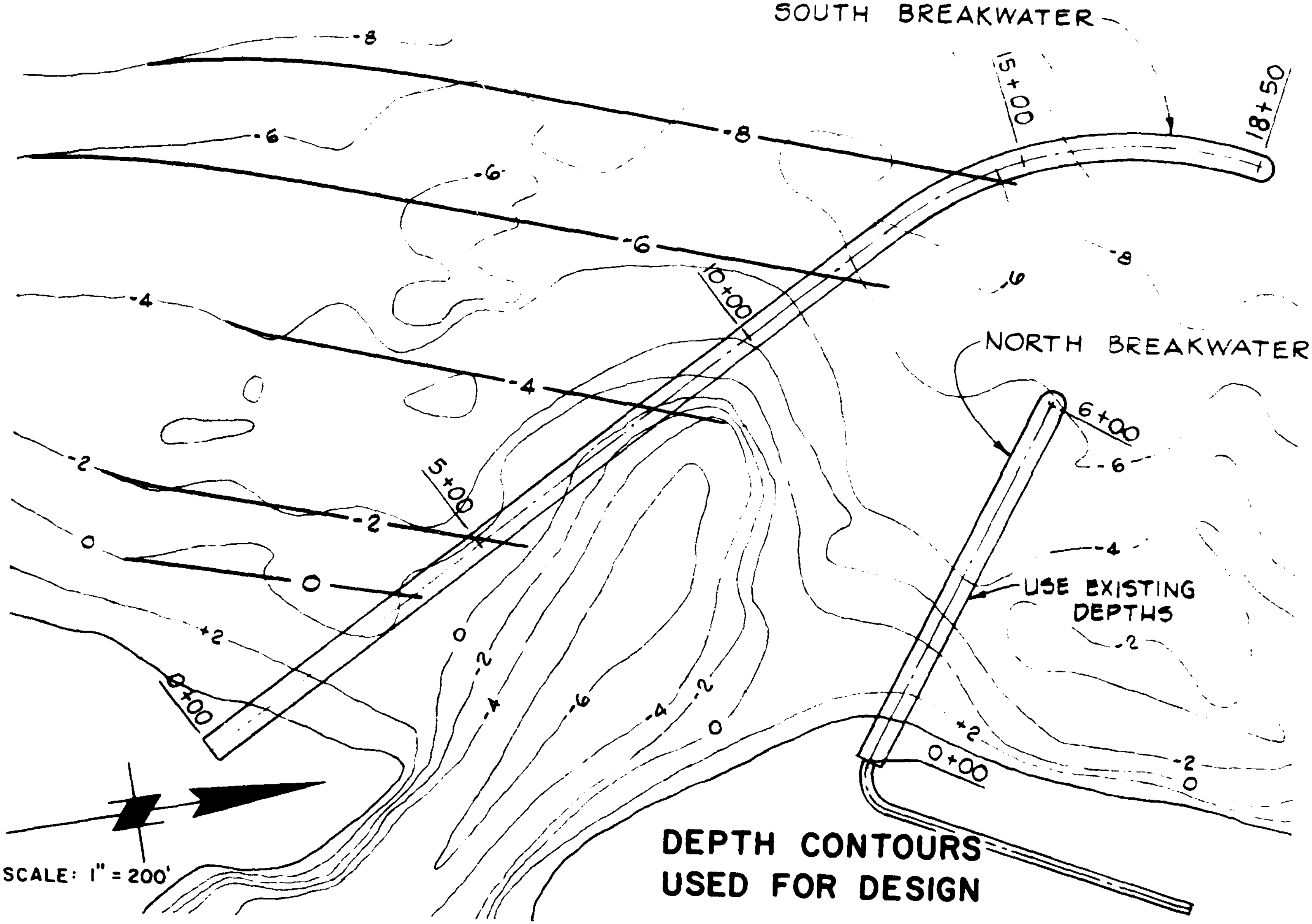
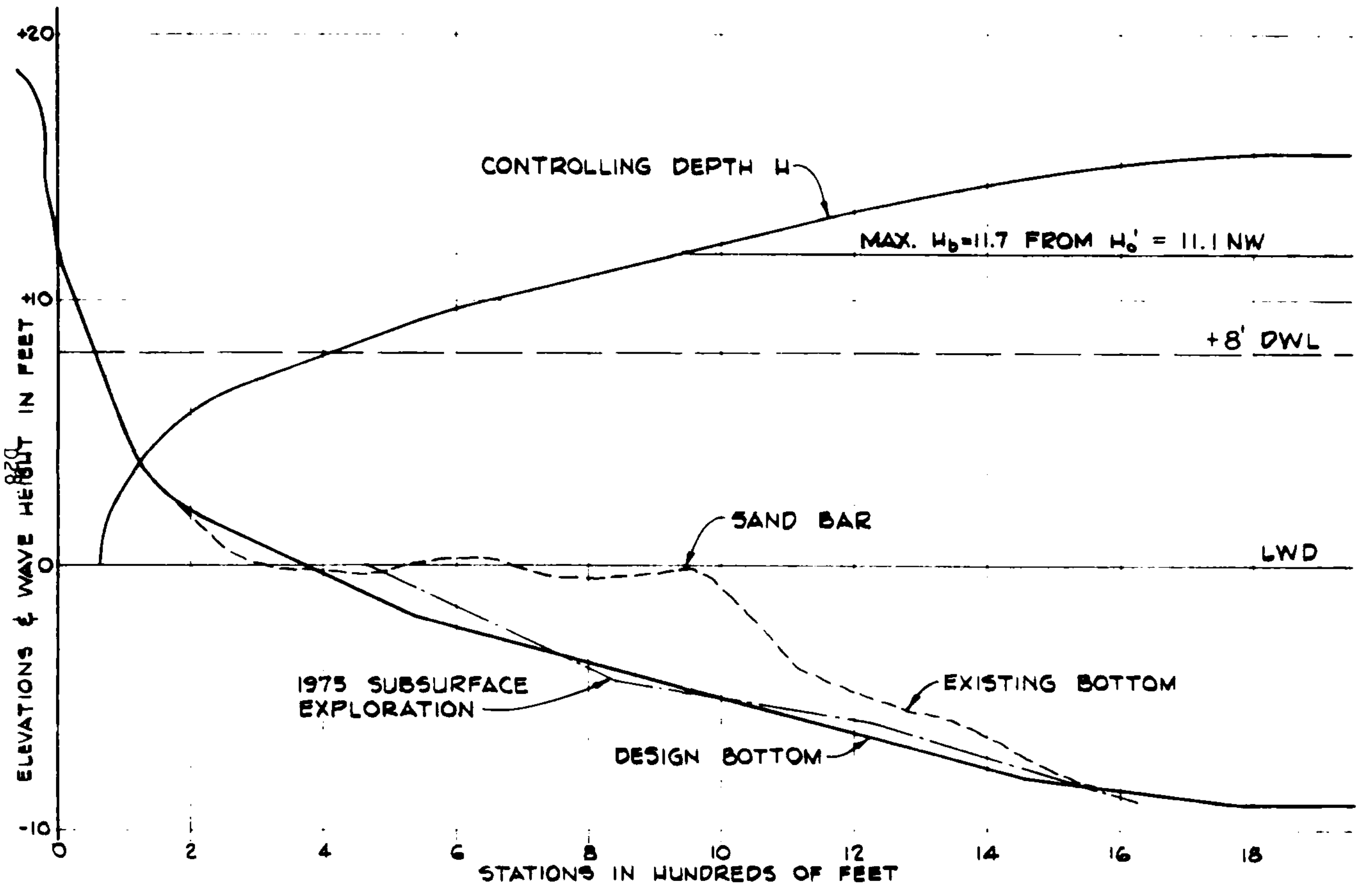

SOUTH BREAKWATER
NORTH BREAKWATER
18+50
15+00
10+00
5+00
0+00
6+00
0+00
USE EXISTING DEPTHS
-8
-6
-4
-2
0
+2
SCALE: 1" = 200'
DEPTH CONTOURS USED FOR DESIGN

FIGURE D16



PROFILE SOUTH BREAKWATER

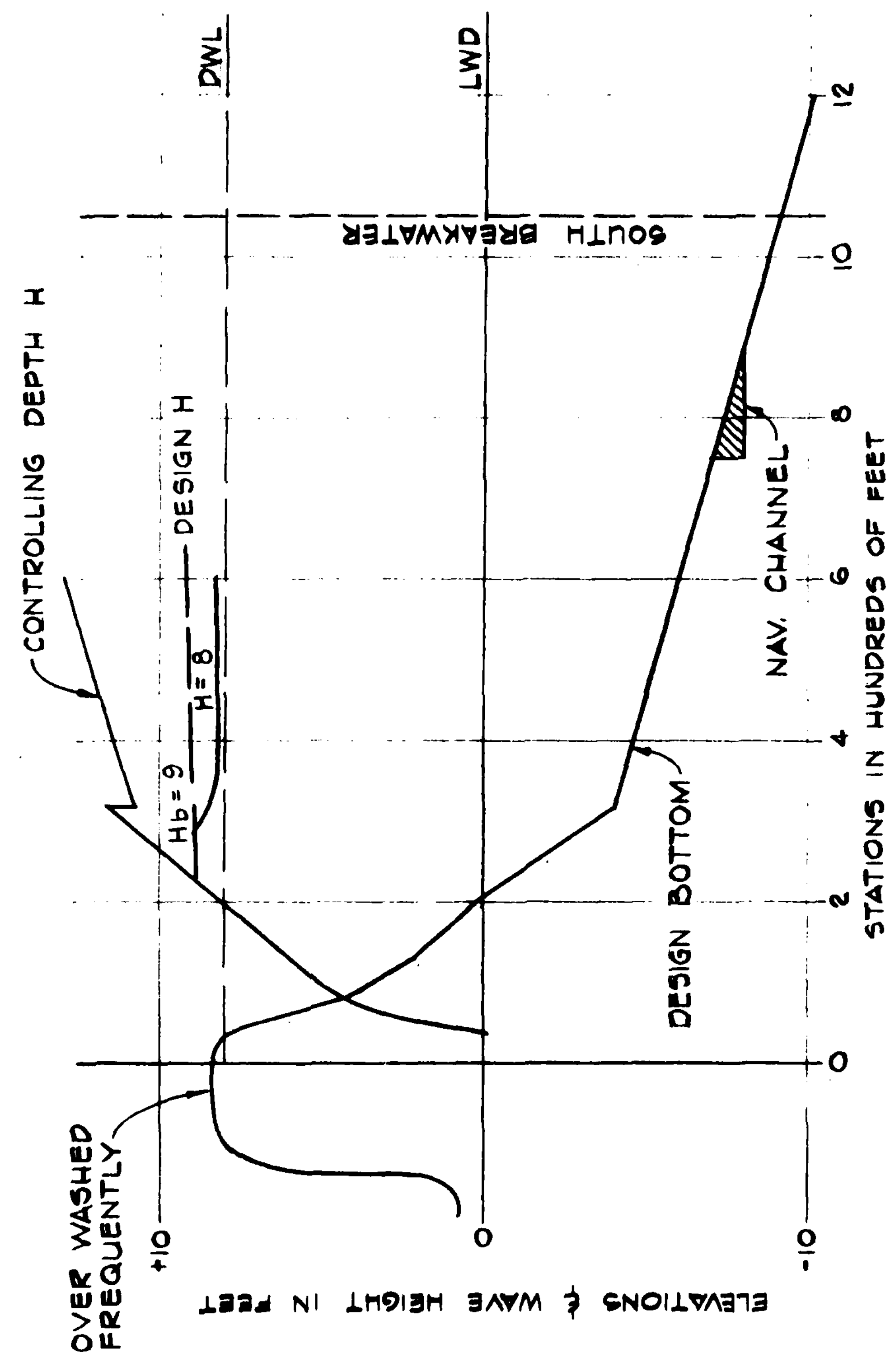
FIGURE D17

water passes over this ephemeral feature. The sand bar was not evident during soundings taken during the 1975 subsurface explorations. Design depths were based on the assumption that the sand bar was not present. The bottom contours were assumed to be interpolations of the neighboring contours present on the reaches to the north and south. The assumed design contours are shown in Figure D16 and the design profile in Figure D17.

D13. The north breakwater is rooted on a sand spit on the north side of the creek. The elevation and plan configuration of the sand spit vary with wave conditions and river discharge. The elevation of the spit at the origin of the breakwater was at +8 feet LWD during the 1975 survey. The north breakwater extends 600 feet lakeward on an azimuth of 307 degrees to a depth of -7 feet LWD. A profile taken through the centerline of the breakwater is shown in Figure D18.

DESIGN WAVES

D14. The design incident deep-water wave is from the northwest, has a height of 11.1 feet, and a period of 7.8 seconds. The south breakwater is situated in depths of water ranging from -9 feet LWD to +12 feet above water, depending on lake level and location. A bottom slope of 1:50 was selected to determine the design wave. Table D6 presents the depth-controlled breaker height for depths of water ranging from 2 to 17 feet. Calculations are presented in Paragraph D29. The 20-year design wave is an 11.7-foot breaking wave. This wave may break along reaches from 9+50 to 18+50 of the south breakwater, depending on lake level. Depth controls the design wave height for the reaches of the south breakwater shoreward of Station 9+50. The design wave profile is shown in Figure D17 for the south breakwater. Design waves for the north breakwater are decreased by diffraction about the south breakwater. A 9-foot design wave was selected for the north breakwater from Station 2+50 to 6+00. Depth controls height for the shoreward stations. The design wave profile for the north breakwater is shown in Figure D18.



PROFILE NORTH BREAKWATER

FIGURE D18

TABLE D6

DEPTH-CONTROLLED MAXIMUM BREAKER HEIGHT[2]

d_s (ft)	$\frac{d_s}{gT^2}$	$\frac{H_b}{d_s}$[1]	H_b (ft)
2	.00072	1.00	2.0
4	.00144	.98	3.8
6	.00215	.97	5.8
8	.00297	.96	7.7
10	.00359	.95	9.5
12	.00431	.94	11.3
14	.00500	.93	13.0
16	.00575	.92	14.7
17	.0061	.91	15.5

[1]From Figure 7-4, SPM.

[2]T = 9.3 seconds from west.

ARMOR UNITS

D15. Armor unit requirements were calculated by application of Hudson's formula.[3] Stability coefficients were selected for breakwater sections comprising two layers of angular quarrystone randomly placed and subjected to breaking waves. Stability coefficients of $K_d = 2.5$ and 3.5 were selected for the head and trunk sections, respectively. Three design sections were selected representing the south breakwater and two sections representing the north breakwater. The side slopes were selected to be 1:1.5 for trunk sections and 1:2 for head sections. Table D7 summarizes the armor units required for each reach of each breakwater. Six-ton stone is required for the south breakwater. Six-ton stone extends from Station 18+50 to Station 7+00, where only four-ton stone is required. The four-ton stone extends to Station 2+00. One-ton stone is required for shoreward reaches. Three-ton stone is required for Station 6+00 shoreward to Station 2+00 on the north breakwater. One-ton stone is required from Station 2+00 to 0+00. Armor unit calculations are presented in Paragraph D29.

TABLE D7. BREAKWATER ARMOR REQUIREMENTS

South Breakwater

Reach Sta.	to Sta.	Armor	Underlayer
0	2	1 Ton	Core Material
2	7	4 Ton	800 Lb.
7	18+50	6 Ton	1200 Lb.

North Breakwater

Reach Sta.	to Sta.	Armor	Underlayer
0	2	1 Ton	Core Material
2	6+00	3 Ton	600 Lb.

[3] Op.cit.

UNDERLAYER

D16. Underlayers are required to support the armor units. The underlayer is one-tenth the weight of the overlying armor units. A graded underlayer is not required for the sections having one-ton armor because a core material underlayer will provide adequate support for one-ton armor stone. The loss of fines in the core material layer should cause initial settlement of the structure.

CORE AND PROTECTION

D17. An impermeable core is required to prevent littoral drift from passing through the breakwater and to form a transition between the underlayer stone and the bedding course. The core material comprises stone weighing 1000 pounds and a minimum size of 1". The larger stones will support the armor and underlayer, and the smaller stones will prevent loss of fines from the bedding course. A 3-foot-thick layer of quarry run should provide adequate support for the structure. The core extends 5 feet beyond armor stone, forming a toe. This toe protection is required to prevent toe scour. A natural filter should form within the core with the loss of fines, resulting in some minor initial loss.

BEDDING LAYER

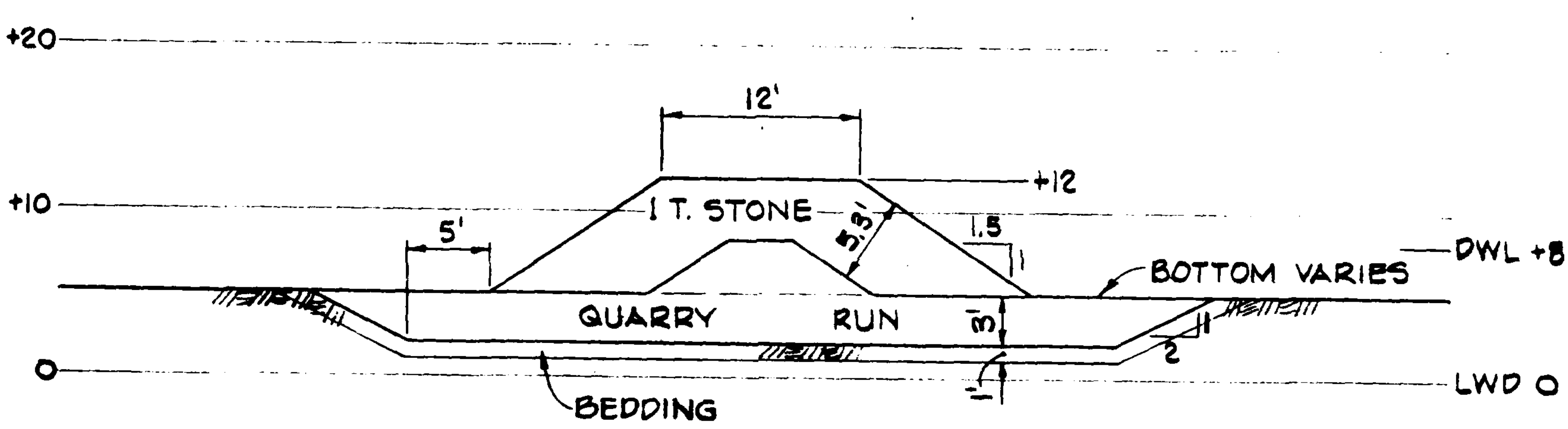
D18. A bedding layer is required to provide a firm foundation for the breakwater. The lake bottom comprises a loosely compacted stratum of fine alluvial sand from the Cattaraugus sediment load. The bottom shifts rapidly in response to changes in river flow, lake level, and wave conditions. A gravel bedding placed in a 1-foot layer should prevent loss of fines from the in-situ soils, which could otherwise result in excessive settlement.

DESIGN SECTIONS

D19. Typical design cross-sections are shown in Figures D19 through D23 for the south breakwater and in Figures D24 through D26 for the north breakwater. The sections shown are typical. In some cases, the breakwater will require the bottom to be excavated as indicated in the profiles in Plate 2. This is necessary in order to have the crest elevation at +12 feet and have an underlayer. The sections shoreward of Station 7+00 are embedded to protect the toe from undermining the armor stone. The south breakwater has a concrete cap from Station 1 to 18+50. The concrete cap is not designed for the first 100 feet of the breakwater. The breakwater along this reach is embedded into the sand dune. Figures D19 and D20 show the two sections of the south breakwater which use 1-ton stone. The first 100 feet of breakwater will be subjected to wave runup, but not a breaking wave. The core is the most important requirement along this reach.

D20. The section in Figure D21, using 4-ton armor, does not have a core in the near-shore reaches. This section requires an impermeable barrier to prevent sand from passing through the voids of the underlayer. A lining of filter cloth would be sufficient to prevent sand from passing through the voids. The filter is to be placed in the underlayer from the core material to the armor stone for Station 2+00 to 7+00. This measure should accommodate the fillet which should accrete as a result of the south breakwater trapping littoral drift. The filter cloth may tear during placing and in structure settlement; however, a small percentage of littoral drift may pass through the breakwater without significant adverse consequences. The filter cloth should be placed with loose folds to allow for settlement and shifting of the stones and to reduce the possibility of tears from occurring.

D21. The north breakwater should also be impermeable to prevent littoral drift from passing through the breakwater and depositing in the basin during episodes of northerly wave attack. A fillet should form on the north side of the north breakwater. The slope of the fillet will be in equilibrium with wave diffraction patterns about the south breakwater and direct northerly wave attack. A plastic filter cloth diaphragm should be placed through armor and underlayers from Stations 0+00 to 3+00.

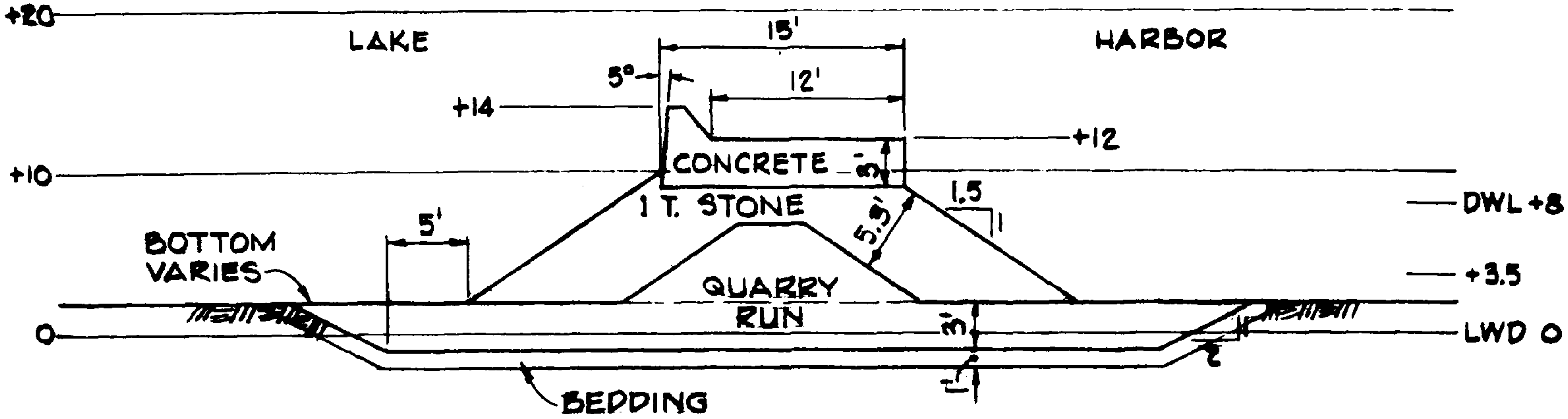


SOUTH BREAKWATER

STA. 0+00 TO STA. 1+00

SCALE: 1" = 10'

FIGURE D19

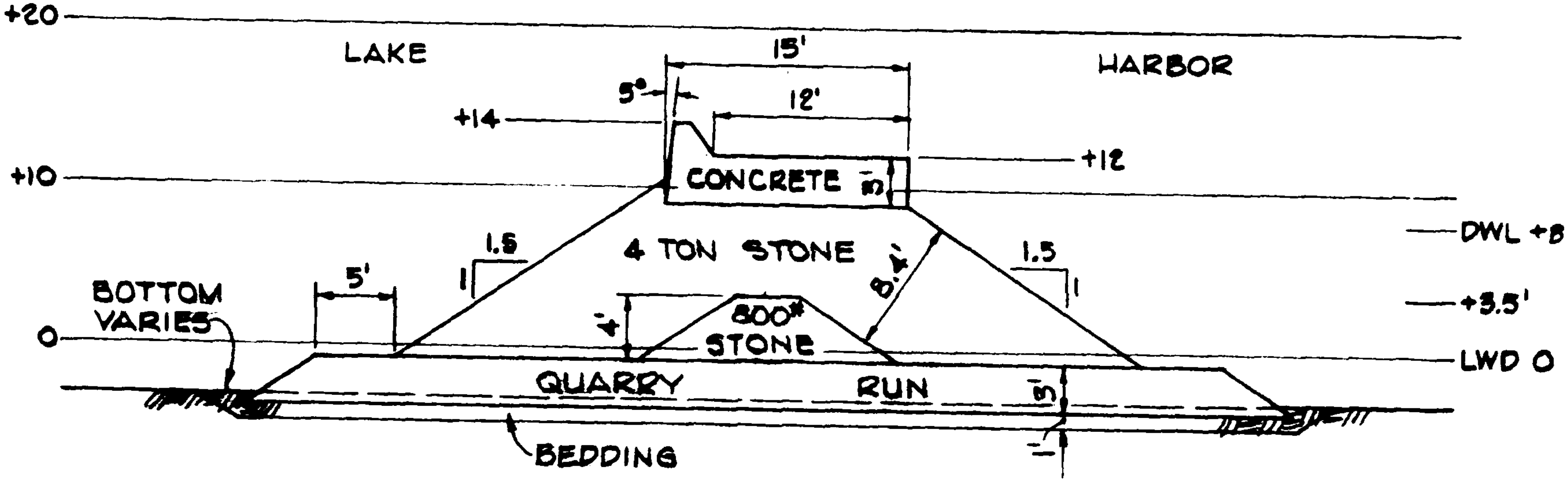


SOUTH BREAKWATER

STA. 1+00 TO STA. 2+00

SCALE : 1" = 10'

FIGURE D20

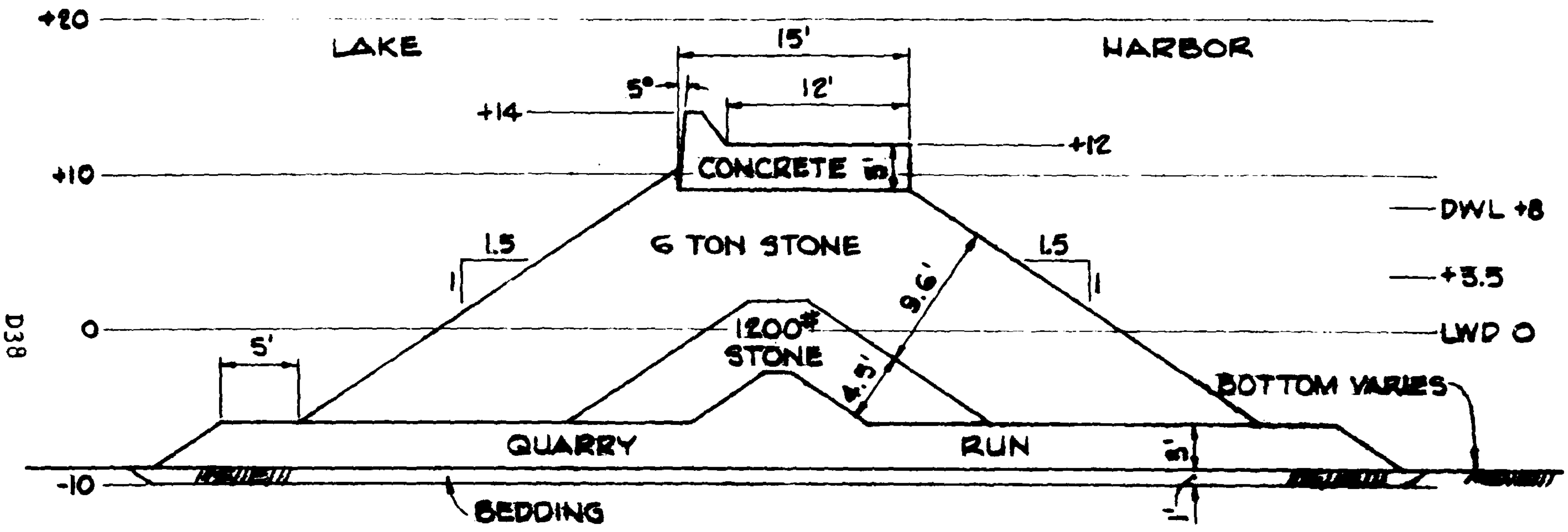


SOUTH BREAKWATER

STA. 2+00 TO STA. 7+00

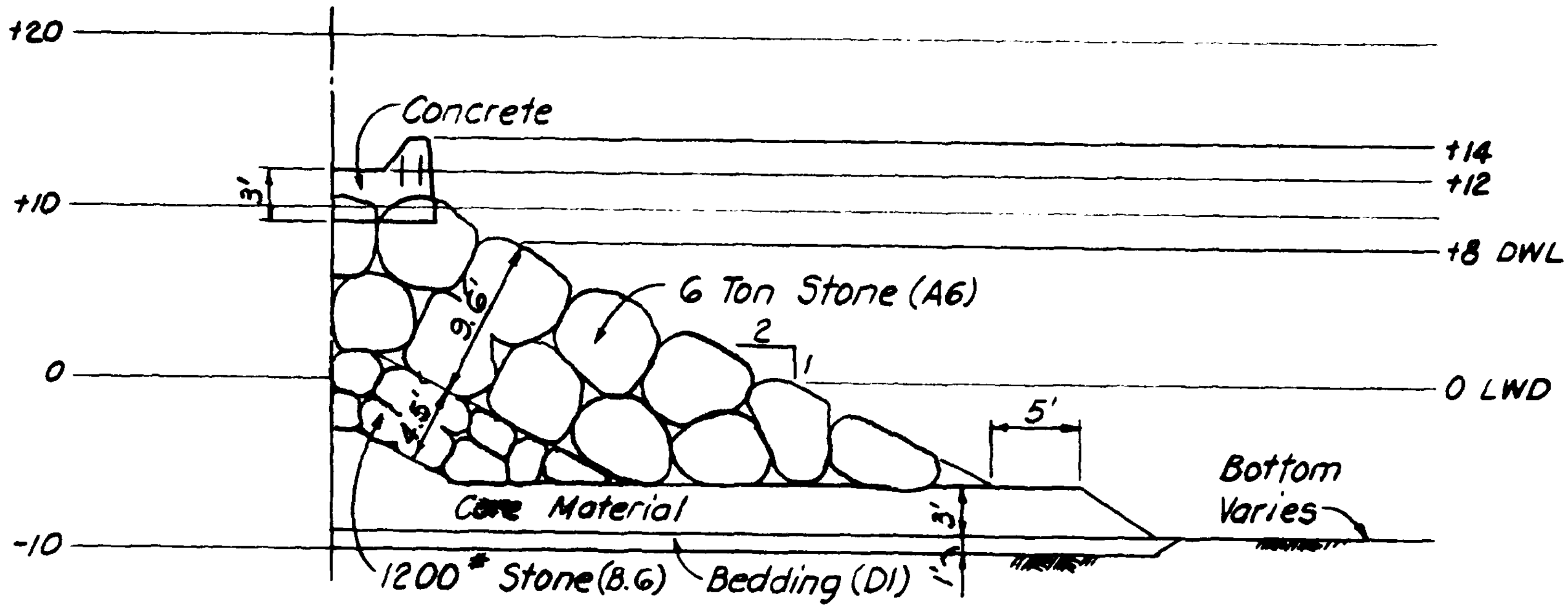
SCALE : 1" = 10'

FIGURE D21



SOUTH BREAKWATER
STA. 7+00 TO STA. 18+50
SCALE: 1" = 10'

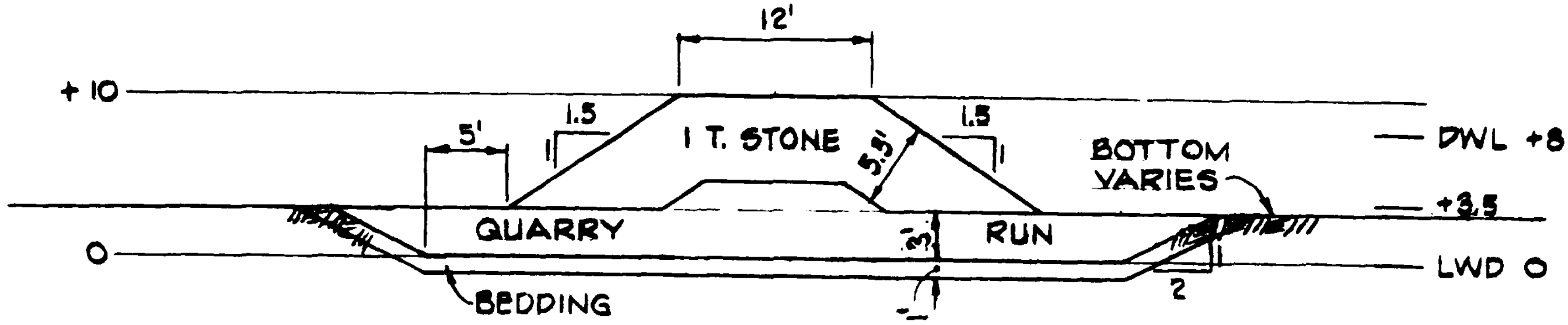
FIGURE D22



SOUTH BREAKWATER - HEAD SECTION

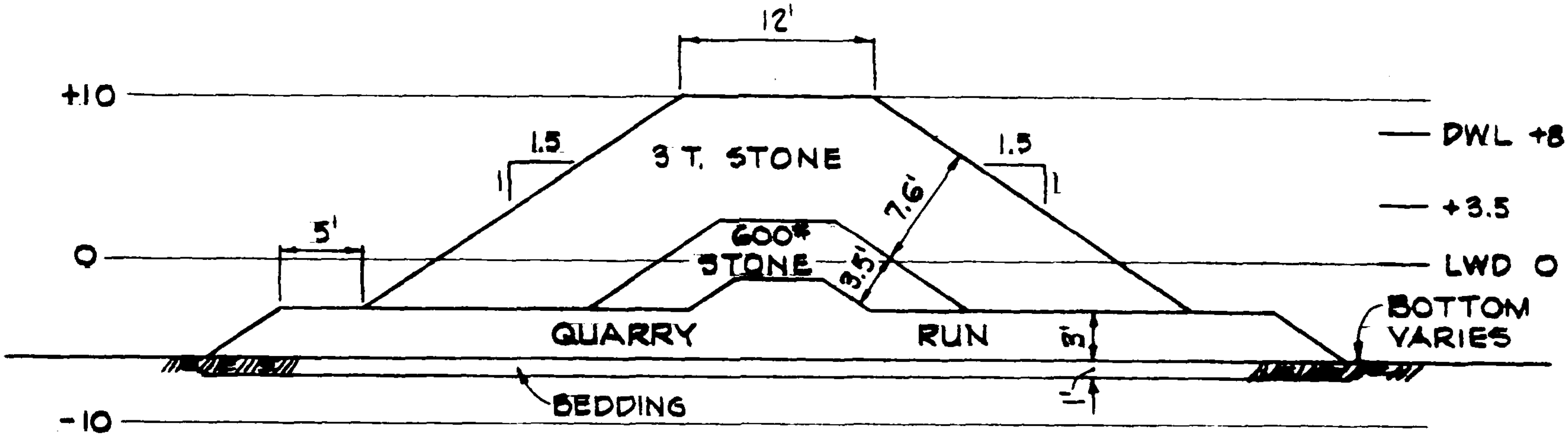
SCALE : 1" = 10'

FIGURE D23



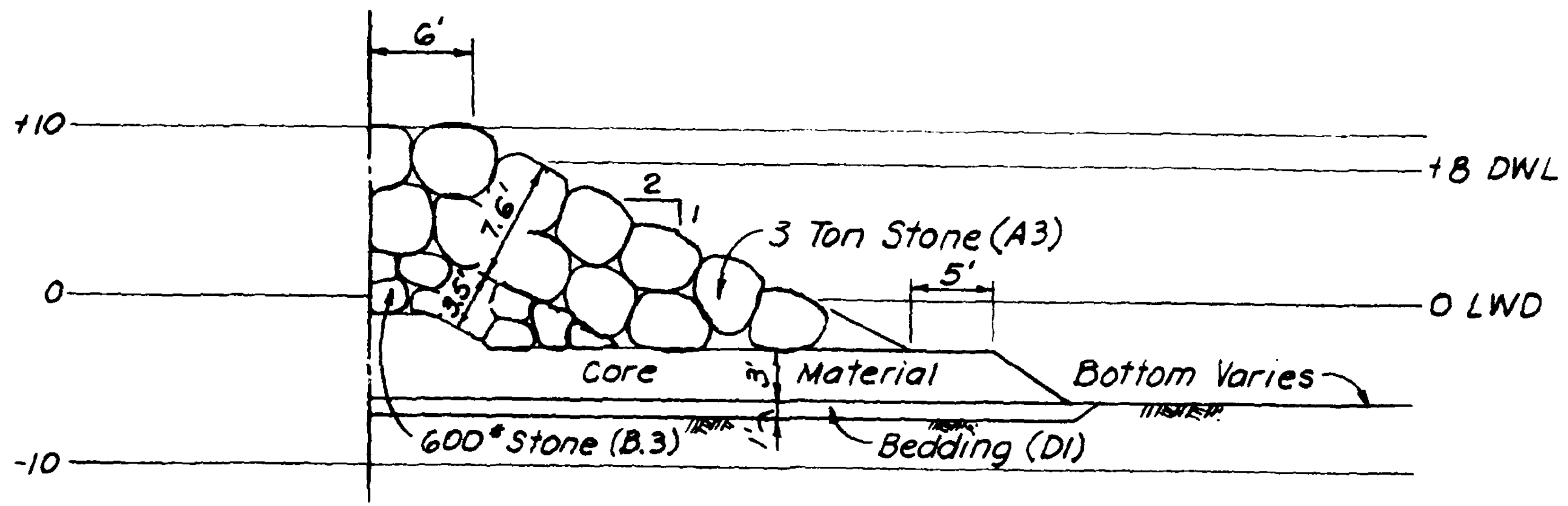
NORTH BREAKWATER
STA. 0+00 TO STA. 1+00
SCALE: 1" = 10'

FIGURE D24



NORTH BREAKWATER
STA. 1+00 TO STA. 6+00
SCALE: 1" = 10'

FIGURE D25



NORTH BREAKWATER - HEAD SECTION

SCALE: 1" = 10'

FIGURE D26

CREST ELEVATION

D22. The crest elevation proposed in the Phase I General Design Memorandum was +10 feet LWD, with a design water surface of +6 feet LWD, leaving four feet of freeboard above the design water surface. The model study tested breakwater sections with the crest elevation at +10 feet LWD, using a 6.8-foot design water level. These design water levels represent monthly and annual recurrence levels, respectively. The 20-year recurrence water level is +8 feet LWD. A crest elevation of +10 feet LWD would leave two feet of freeboard. Severe wave overtopping and possible damage to the back slope would result with such a section under storm conditions. Traditionally, rubblemound breakwaters have been built with crest elevations from one-half to one wave height above the design water level. Structures with lower crest elevations have not had adequate model testing, field experience, or established design criteria.[5] Consequently, without the aid of a model study to determine the required weight of armor units on the back slope, a minimum crest elevation of 0.5H above the design water surface was selected. With H = 11.7 feet and the design water surface 8 feet LWD, the minimum crest elevation of +14 feet LWD was selected. The breakwater crest elevation should also be high enough to afford adequate protection to the harbor from wave overtopping.

D23. The Barcelona breakwater is frequently and severely overtopped. This structure has a crest elevation of +11 feet LWD, but has a 1.5-foot lower design water level than Cattaraugus. The Cattaraugus breakwater, if exposed to similar wave attacks, would be subjected to similar overtopping with a 12.5-foot crest height above LWD. Consequently, a higher crest elevation was selected for Cattaraugus Harbor. The crest elevation selected for design was +14 feet LWD. This elevation reduces height of waves transmitted over the crest and through the voids of the breakwater in the navigation channel at the river mouth to meet established criteria. The transmitted wave height calculations are enclosed in Paragraph D29.

---

[5] Walker, J. R.; R. Q. Palmer, and J. W. Dunham, "Breakwater Back-Slope Stability," Proceedings of ASCE, Civil Engineering in the Oceans/III, Newark, Delaware, 1975.

CROWN WIDTH

D24. The crown width selected was based on construction and maintenance access requirements, wave overtopping rates and stability of armor on the crest and back slope. A minimum 12-foot construction road is generally required to construct a breakwater from a land-based operation. Groins may be constructed with narrower crest widths by building the structure at the core or underlayer elevation going lakeward and placing the cap stone returning landward. This, however, does not leave adequate room for maintenance on a breakwater. The crown width also has bearing on the transmitted wave height, as indicated by the transmitted wave height curves in Shore Protection Manual, SPM. The crown must also have a minimum of 3 stone diameters width for stability purposes. A 15-foot crest was selected for design based on the considerations presented above.

CONCRETE CAP ON A RUBBLE STRUCTURE

D25. Concrete caps are designed along the crests of breakwaters to strengthen the crest, increase the crest height, and provide a walkway and maintenance roadway. Concrete caps are a rigid structure subject to massive failure. Large hydrostatic pressures can build between the cap and underlying stone and shock pressures can develop on the lakeward face. Settlement of armor stone can cause cracking and massive failure of the breakwater. For these reasons, care should be exercised in design and construction of concrete caps. Concrete caps on rubble structures are discussed in the Shore Protection Manual (SPM). Failures of such structures may result from:

(a) Sliding of the cap, e.g. W.E.S. model tests of Nawiliwili breakwater;

(b) Undermining, e.g. (1) Kahuliu breakwater and (2) Humboldt jetties;

(c) Differential settlement of recently constructed rubble structures.

The concrete cap should be integrated with the underlying stone to reduce the potential for sliding. Concrete poured over and around the cap stones will provide some integration of the cap to the stone. Bonds between the stone and concrete are not adequate to ensure that each underlying stone is permanently integrated into the cap and, therefore, bonds cannot be relied upon for integration. The concrete is unreinforced.

D26. In view of the probable differential settlement and consolidation of new rubble structures, the cap is articulated by providing open construction joints about every 15 feet. A 2-inch-wide joint would also serve as a vent to relieve uplift pressures during high wave attack. A parapet is designed on the lakeward side of the cap to reduce wave overtopping by effectively raising the crest of the breakwater. The parapet has a 5-degree batter sloping toward the basin to reduce the possibility of ice lifting the cap. The parapet is to be constructed in a second concrete pour. The parapet is attached to the cap with reinforcing bars.

D27. A safety handrail is required on the crest of the breakwater. The handrail is a chain link railing supported by 3.5-foot high, 2-inch diameter pipe stanchions spaced 10 feet on centers along the creek side of the south breakwater cap. The stanchions are mounted on anchor bolts embedded in the concrete cap. This will render the stanchions more adaptable to repair.

SETTLEMENT AND SLOPE STABILITY

D28. The foundation soils upon which the breakwaters will be constructed have adequate bearing capacity to support the anticipated loads. Minor compression of the alluvial and outwash silt, sand, and gravel deposits of 2 to 3 inches is anticipated. Calculations of foundation settlement are given in Paragraph D29. An analysis of slope stability of the rubble structure in Paragraph D29 indicates a minimum safety factor of 1.12 for the concrete cap section. The analysis assumed a 150 psf live load on the concrete cap. The live load accounts for maintenance vehicles and public access. The analysis made by computer used the Swedish Circle method. The critical failure circle was determined by a trial-and-error method. The diagram shows the assumed failure circles and the tabulation gives the factor of safety.

D29. Calculations:

1. Design Wave (Pages D47-D48)
2. Breakwater Armor Stone Calculations (Pages D49-D51)
3. Crest Elevations (Pages D52-D57)
4. Settlement Analysis (Pages D58-D61)
5. Slope Stability (Pages D62-D63)

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BED	JOB NO.	
	PROJECT CATT.	SHEET 1 OF	
	CALCULATIONS FOR DESIGN WAVES	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12-75

DESIGN WAVE CALCULATIONS

Calculate max. H_b for south breakwater

wave NW, T = 7.8 sec, $H_0' = 11.12'$

$$\frac{H_0'}{gT^2} = \frac{11.12}{g\,7.8^2} = .0057$$

From FIG 7-3 SPM
$m = .02$

$$\frac{H_b}{H_0} = 1.05$$

$$H_b = (1.05)(11.12) = 11.7'$$

calculate breaker depth

$$\frac{H_b}{gT^2} = .006$$

$$\frac{d_b}{H_b} = 1.18 \rightarrow 1.5 \quad \text{(FROM FIG 7-2, SPM)}$$

$d_b = 13.8 \rightarrow 17.6$

$d_s = +14$ to $-8'$ LWD $+ 0 \rightarrow 8'$ LL.

$d_s' = +6$ to $-16'$

d_s IN range of depths.

H = 11.7' Design wave, depth controlled in shore.

Summary

DIR	H_b ft.	T sec	Az °	d_b
NNE	3.1	6.7	293	3.3 → 4.6
N	7.2	7.0	296	8.3 → 10.7
NW	11.7	7.8	310	13.8 → 17.6
W	11.6	9.3	330	13.3 → 17.4
WSW	10.9	9.8	328	12.9 → 16.4

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT DED	JOB NO.	
	PROJECT CATT.	SHEET 2 OF 2	
	CALCULATIONS FOR DESIGN WAVE	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12-75

DESIGN WAVE - NORTH BREAKWATER

DIFFRACTION STUDY

NW WAVE $T = 7.8$, $H_0' = 11.12$

$K_0 = .45$ head

$= .6$ TRUNK

$H_0' = .45(11.12) = 5'$ head

$= .6(11.12) = 6.7$ TRUNK

DESIGN BREAKER

$m = .0133$ STA 34 → 67

$$\frac{H_0'}{gT^2} = \frac{6.7}{g\,7.8^2} = .00342$$

$$\frac{H_b}{H_0'} = 1.15$$

$H_b = 7.7$

$m = .035$ STA 07 → 34

$$\frac{H_0'}{gT^2} = \frac{6.7}{g\,7.8^2} = .00342$$

$$\frac{H_b}{H_0'} = 1.3$$

$H_b = 8.7$

USE $H_b = 9.0'$

Quarry Stone

South B/W

HUDSONS FORMULA

$$W = \frac{\gamma_r H^3}{K_r \cot\theta \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3}$$

$\gamma_r = 165$ pcf
$\gamma_w = 62.4$

$$W = 37.12 \frac{H^3}{K_D \cot\theta}$$

TRUNK

select $K_D = 3.5$ 2 layer random placement, (SPM sect. 7)

$\cot\theta = 1.5$

$$W = 7.07 H^3$$

H	12	11.7	10	8	6	4	2
W TONS (Lbs.)	6.11	5.66	3.5	1.81	(1527)	(452)	(57)

head	K_D	$\cot\theta$	$W_{(H=11.7)}$
	2.9	1.5	6.8
	2.5	2.0	5.95
	2.0	3.0	4.95

select 6 TON STONE ALT 3, H = 11.7'
$\cot\theta = 2$ head
$\cot\theta = 1.5$ TRUNK

select 4 TON STONE ALT 2 H = 10'
select 1 TON STONE ALT 1 H = 6'

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT DED	JOB NO.	
	PROJECT CATT.	SHEET 2 OF 3	
	CALCULATIONS FOR ARMOR B/U	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12 75

armor thickness

$r = n K_\Delta \left(\frac{W}{\gamma}\right)^{1/3}$

1 TON ALT 1

$r = 2 \cdot 1.15 \left(\frac{2000}{165}\right)^{1/3} = 5.3'$

min crest width $= 3/2\, r = 8'$

select 12' for construction purposes

underlayer

$W = W_a/10 = 200$ Lb

$r = 2 \cdot 1.15 \left(\frac{200}{165}\right)^{1/3} = 2.5'$

4 TON ALT 2

$r = 2 \cdot 1.15 \cdot \left(\frac{8000}{165}\right)^{1/3} = 8.4'$

$b_{min} = 3/2\ 8.4 = 12.5'$

select $b = 15$ for matching with other alts., stability

underlayer

$W = \frac{8000}{10} = 800$

$r = 2 \cdot 1.15 \left(\frac{800}{165}\right)^{1/3} = 3.9$ say 4'

6 TON ALT. 3

$r = 2 \cdot 1.15 \left(\frac{12000}{165}\right)^{1/3} = 9.6'$

$b = 3/2\ 9.6 = 14.4$ - Select $b = 15'$

underlayer

$W = W/10 = \frac{12000}{10} = 1200$

$r = 2 \cdot 1.15 \left(\frac{1200}{165}\right)^{1/3} = 4.5'$

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BED	JOB NO.	
	PROJECT CATT.	SHEET 3 OF 3	
	CALCULATIONS FOR QUARRY STONE / B/W	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12.75

North B/W

$$W = 37.12 \frac{H^3}{K_d \cot\theta}$$

$K_d = 3.5$

$\cot\theta = 1.5$

$H = 9$ ALT

TRUNK

$$W = 37.12 \frac{9^3}{1.5 \cdot 3.5}$$

$= 2.6$ TONS

head $H = 8$

K_d =	$\cot\theta$	$W_{H=8}$	$W_{H=9}$
2.9	1.5	2.18	3.11
2.5	2	1.90	2.71

select $W = 3$ TON
TRUNK $\cot\theta = 1.5$
head $\cot\theta = 2$

Thickness

$r = 2 \cdot 1.15 \left(\frac{6000}{165}\right)^{1/3} = 7.6$

$b = 3/2 \; 7.6 = 11.4$ MIN

Select $b = 12'$

underlayer

$W = W/10 = 600$ LB

$r = 2 \cdot 1.15 \left(\frac{600}{165}\right)^{1/3} = 3.5'$

STATIONS D-1, SELECT 1 TON STONE

see page 2 - ALT 1

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT B. E. D.	JOB NO. L-1612	
	PROJECT CATTAUAUGUS	SHEET 1 OF 6	
	CALCULATIONS FOR CREST ELEVATION	DESIGNED BY KW	DATE 9-75
	TRANSMITTED WAVES	CHECKED BY WB	DATE 12-75

CALCULATE TRANSMITTED WAVE HEIGHT AT RIVER MOUTH

CRITERIA: $H < 2.5'$ AT CREEK MOUTH
20 YEAR RECURRANCE
$H < 0.5'$ IN MOORING AREA

REF. CROSS, R.H. AND C.K. SOLLITT
"WAVE TRANSMISSION BY OVERTOPPING"
J. WATER WAYS AND HARBOR DIV. A.S.C.E.
WW3 AUG. 1972

FIG. 7 OF ABOVE REF. GIVES $H_t/H_i = f\left(\frac{h_e}{R}\right)$
WHERE h_e IS CREST ELEVATION ABOVE S.W.L.
R IS HYPOTHETICAL RUN UP

REF. GIVES UPPER BOUND OF ALL DATA

$$H_T/H_i = 0.65\,(1.1 - h_e/R)$$

THE ABOVE EQUATION IS SHOWN IN FIG. 4 TO BE PLOTTED WITH THE DATA POINTS. THE EQUATION IS PLOTTED INCORRECTLY AS INDICATED.

THE DATA USED BY REF. ARE NOT IN RANGE OF PROTOTYPE APPLICATION. THE DATA ON DANA PT. IS APPLICABLE. 3 DATA. POINTS FROM S.P.M. CURVES ARE PLOTTED IN THE FIGURE. THESE CALCS. ARE GIVEN ON THE FOLLOWING PAGES. A MODIFIED EQUATION IS SUGGESTED TO FIT THE DANA PT. AND S.P.M. DATA.

$$H_T/H_i = 0.55\,(1.05 - h_e/R)$$

THIS EQUATION IS PLOTTED IN FIG. 4.

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BED	JOB NO. L-1612	
	PROJECT CATT	SHEET 2 OF 6	
	CALCULATIONS FOR Ht	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12 75

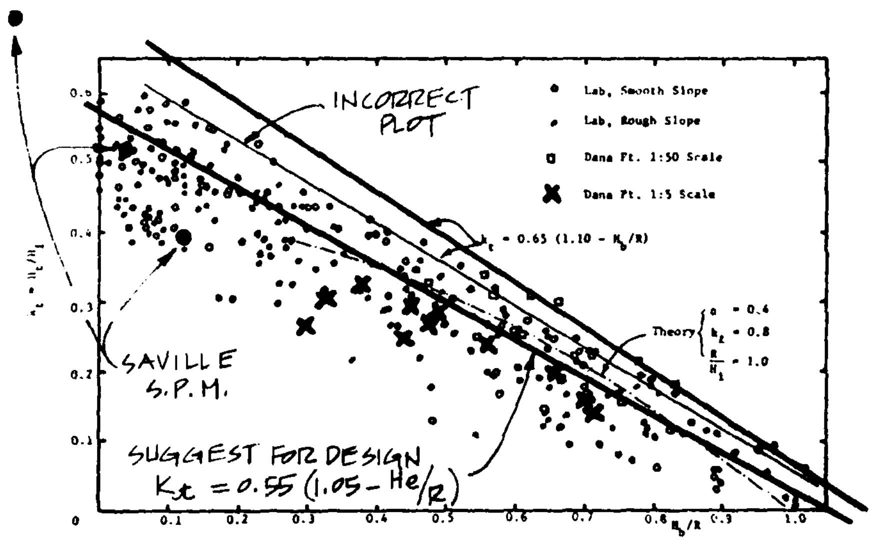


FIG. 7.—k_t VERSUS H_b/R. ALL LAB DATA AND DANA POINT MODEL DATA

(AFTER CROSS AND SOLLIT, 1972)

FIGURE 4 : TRANSMITTED H

× DANA PT. PLOTS 1:5 SCALE AND SAVILLE S.P.M. DATA ARE INCLUDED.

INCORRECT PLOT OF C & S TOO CONSERVATIVE

REC. $H_T/H_i = 0.55\,(1.05 - h_e/R)$ AS SHOWN

MOFFATT & NICHOL, ENGINEERS, LONG BEACH, CALIFORNIA	CLIENT BED	JOB NO L-1612	
	PROJECT CATT	SHEET 3 OF 6	
	CALCULATIONS FOR H_t	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12-75

PLOT – S.P.M. DATA ON CURVE FIG. 4
S.P.M. (SAVILLE) DATA TRANSFORMED TO CROSS AND SOLLITT GRAPH

FIG. 7-37 S.P.M.

FOR $h/d_s = 1.133$

FOR $d_s = 17$

$H_i = 12$

$T = 8$

$$\frac{d_s}{gT^2} = \frac{17}{g8^2} = 0.00824$$

$$\frac{H_i}{gT^2} = \frac{12}{g8^2} = 0.00582$$

FOR $b = 15$ CREST WITH

$h = 19.3$ ($h = 1.133\, d_s$)

$b/h = 0.78$

$H_T/H_i = 0.3 - 0.4$

RUN UP

$d/H = \frac{17}{12} = 1.4$

$\cot\phi = 1:2$

$R/H_o' = 2.4$ (1:1.5 SAME)

REDUCE FOR POROSITY – 1.2 FOR SCALE

$R/H_o' = 2.4 \times 0.5 \times 1.2 = 1.44$

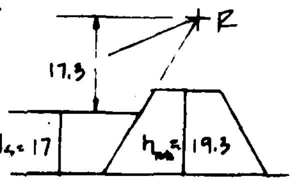
$H_o' = 12$

$R = 17.3$

CREST = 2.3 = h_e

$h_e/R = \frac{2.3}{17.3} = 0.13$

PLOT FOR $H_T/H_i = 0.4$



MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BEO	JOB NO. L-1612	
	PROJECT CATT	SHEET 4 OF 6	
	CALCULATIONS FOR H_t	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12-75

FOR $h/d_s = 1.033$ (S.P.M.)

$d_s = 17$

$h = 1.033 \times 17 = 17.6$

$\frac{H}{gT^2} = \frac{12}{32.2 \times 8^2} = 0.00582$

$\frac{d_s}{gT^2} = \frac{17}{32.2 \times 8^2} = 0.00824$

$H_T/H_i = 0.54$

RUN UP

$R/H_o' = 2.3$

$R = 2.3\,(1.2)\,(0.5)\,12 = 16.5$

$h_e/R = \frac{0.6}{16.5} = 0.04$ PLOT FOR $H_T/H_i = 0.54$

FOR $h/d_s = 0.899$

$H_T/H_i = 0.7$ FIG. 7-36 S.P.M.

$R/H_o' = 16.5$ (PREVIOUS CALC.)

$h = 0.899\,(17) = 15.3$

$h_e/R = \frac{-17 + 15.3}{16.5} = -0.10$ PLOT FOR $H_T/H_i = 0.7$

CALCULATE H_t FOR CATTAURAUGUS TRANSMITTED WAVE

USE $H_o' = 12'$, $T = 8$ SEC.

RUN UP FROM PAGE 4 $R = 16.5'$

DETERMINE H_T IN RIVER ENTRANCE

PROCEEDURE

FOR +8 LWD WATER LEVEL

CALCULATE H_T

REDUCE FOR ANGULAR SPREADING OF WAVE ENERGY BY:

gap = 300' BETWEEN b/w's

gap = 750'

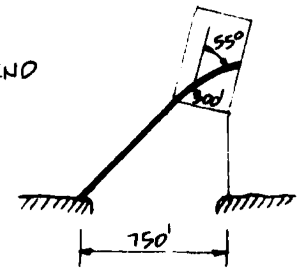
$$K_r = \sqrt{\frac{300}{750}} = 0.63$$

H_T REDUCED BY SOME FUNTION OF ANGLE OF INCIDENT – ASSUME

$$H_T = H_{T90°} \sin X$$

AVE. $\alpha = 50°$ FOR OUTER END

$$\sin \alpha = 0.77$$



$$K_r = 0.77 \times 0.63 = 0.49$$

USE 0.5

SEE TABLE NEXT PAGE FOR CALCULATION OF H AT RIVER MOUTH

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BEU	JOB NO. L-1612	
	PROJECT catt	SHEET 6 OF 6	
	CALCULATIONS FOR H_t	DESIGNED BY KW	DATE 9-75
		CHECKED BY WB	DATE 12-75

TABLE : H_T AT RIVER MOUTH

CREST ELEVATION ABOVE D.W.L. = 8' (he)	H_T (FT.)	H_T (FT.) MOUTH
2	6.1	3.1
4	5.3	2.7
6	4.5	2.3
8	3.7	1.9
10	2.9	1.5
12	2.1	1.1
14	1.3	0.7
16.5	0.33	0.2

FOR $H_i = 12'$, $T = 8$ SEC.

$$H_T = 0.55\,(1.05 - h_e/R)$$

$$R = 16.5'$$

$h_e = 6$ MEETS CRITERIA AT RIVER MOUTH FOR $H < 2.5'$

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

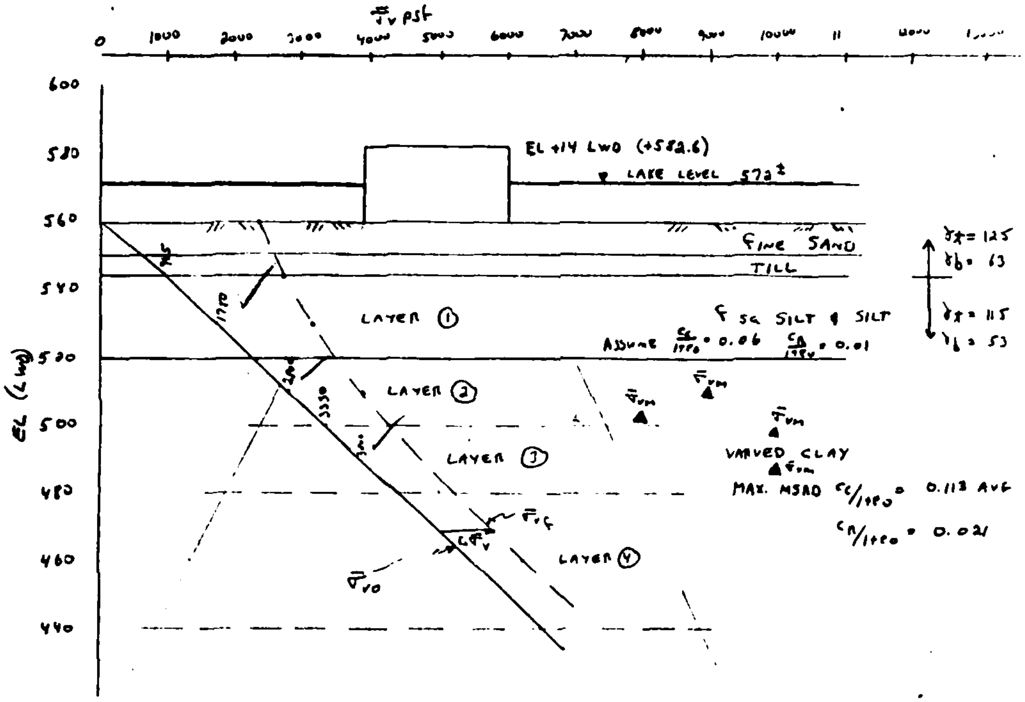
CLIENT: Moffatt Nichol
PROJECT: Cattaraugus Creek
SETTLEMENT ANALYSIS - SOUTH BREAKWATER

FILE NUMBER: 3655
SHEET 1 OF 4
DATE: 10/9/75
COMPUTED BY: EDH
CHECKED BY: DLF

CONSOLIDATION SETTLEMENTS FOR CELLULAR COFFERDAM*

* rubble mound design imposes similar stress and therefore results are similar.

SOIL CONDITIONS AT D-75-17



$\Delta\bar{\sigma}_{vf}$ FROM CELL WITH γ_t = 135 pcf γ_b = 73 pcf

EL (LWD)	DEPTH (FT)	AVG STRESSED WIDTH AT 2V:1H (FT)	$\Delta\bar{\sigma}_{vf}$ (psf)	$\bar{\sigma}_{vf}$ (psf)	$\bar{\sigma}_{vo}$ (psf)
560	0	42	2307 ✓	2307	
545	15	57	1700 ✓	2645	
530	30	72	1345 ✓	3095	1750
510	50	92	1053 ✓	3853	2800
490	70	112	865 ✓	4665	3800
460	100	142	682 ✓	6182	5500

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

CLIENT McFarland-Johnson
PROJECT Cattaraugus Creek

FILE NUMBER 3655
SHEET 2 OF 4
DATE 10/9/75
COMPUTED BY EBK
CHECKED BY DLF

RESULTS OF CONSOLIDATION TESTS

BORING	SAMPLE	$\bar{\sigma}_{vo}$ (TSF)	$\bar{\sigma}_{vm}$ (TSF)	MAX. $\frac{C_c}{1+e_o}$ MEASURED	$\frac{C_\alpha}{1+e_o}$	REMARKS
DH-75-3	U1 55.4'	1.66	N.D.*	0.065	0.01	SAMPLE CONTAINED CONSIDERABLE SAND
DH-75-15	U2 57.2	1.72	4 TO 7 TSF	0.12	0.025	CONTAINED SAND LAYERS
DH-75-15	U1 51.0'	1.53	PERHAPS 4.5 TSF	0.11	0.02	DITTO
DH-75-16	U1 61'	1.8	PERHAPS ≈ 5	0.14	0.025	SILTY VARVED CLAY
DH-75-16	U2 71'	2.1	PERHAPS ≈ 5	0.13	0.025	SILTY VARVED CLAY
			AVG	0.113	0.021	

* N.D. ≡ CANNOT BE DETERMINED FROM CONSOLIDATION CURVES

NOTE: SAMPLE AND SOIL CHARACTERISTICS SUCH THAT $\bar{\sigma}_{vm}$ IS VERY DIFFICULT TO ESTABLISH RELIABLY.

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

CLIENT Moffatt & Nichol
PROJECT Cattaraugus Creek

FILE NUMBER 3633
SHEET 3 OF 4
DATE 10/9/75
COMPUTED BY EJH
CHECKED BY DLF

ASSUME NO POST CONST. SETTLEMENT OF G. SAND & TILL

ASSUME INITIALLY SILTS AND CLAYS O.C. FULL DEPTH

$$\rho_c = \Sigma H \frac{C_R}{1+e_o} \log \frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{vo}}$$

LAYER	ELEV OF AVG POINT	$\bar{\sigma}_{vf}/\bar{\sigma}_{vo}$	$\log \bar{\sigma}_{vf}/\bar{\sigma}_{vo}$	H (IN)	$H \frac{C_R}{1+e_o} \log$
1	530	1.76	0.25	300	0.75
2	510	1.38	0.14	240	0.71
3	490	1.23	0.09	240	0.45
4	460	1.12	0.05	480	0.51

(Layers 2–4: 1.67)

ρ_c = 2.42 IN

IF CLAY EXTENDS 100 FT MORE WOULD GET ABOUT 1 INCH MORE FOR FULLY O.C. CASE

THE FINE SANDS & SILTS, LAYER (1) APPEAR HIGHLY O.C.
MAKE CALC. FOR ρ_c W/ N.C. CLAY

LAYER	$\log \bar{\sigma}_{vf}/\bar{\sigma}_{vo}$	H (IN)	$H \frac{C}{1+e_o} \log$
1	.25	300	0.75
2	.14	240	
3	.09	240	$1.67\left(\frac{.113}{.021}\right) = 8.99$
4	.05	480	

D60

UPPER BOUND ρ_c ≈ 9.75 IN.

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

CLIENT Moffatt & Nichol

PROJECT Cattaraugus Creek

FILE NUMBER 3655
SHEET 4 OF 4
DATE 10/9/75
COMPUTED BY EDH
CHECKED BY DCF

BEST AVAILABLE DATA BOTH GEOLOGICALLY AND FROM LAB. & FIELD DATA INDICATE SILTS AND CLAYS HIGHLY OVERCONSOLIDATED.

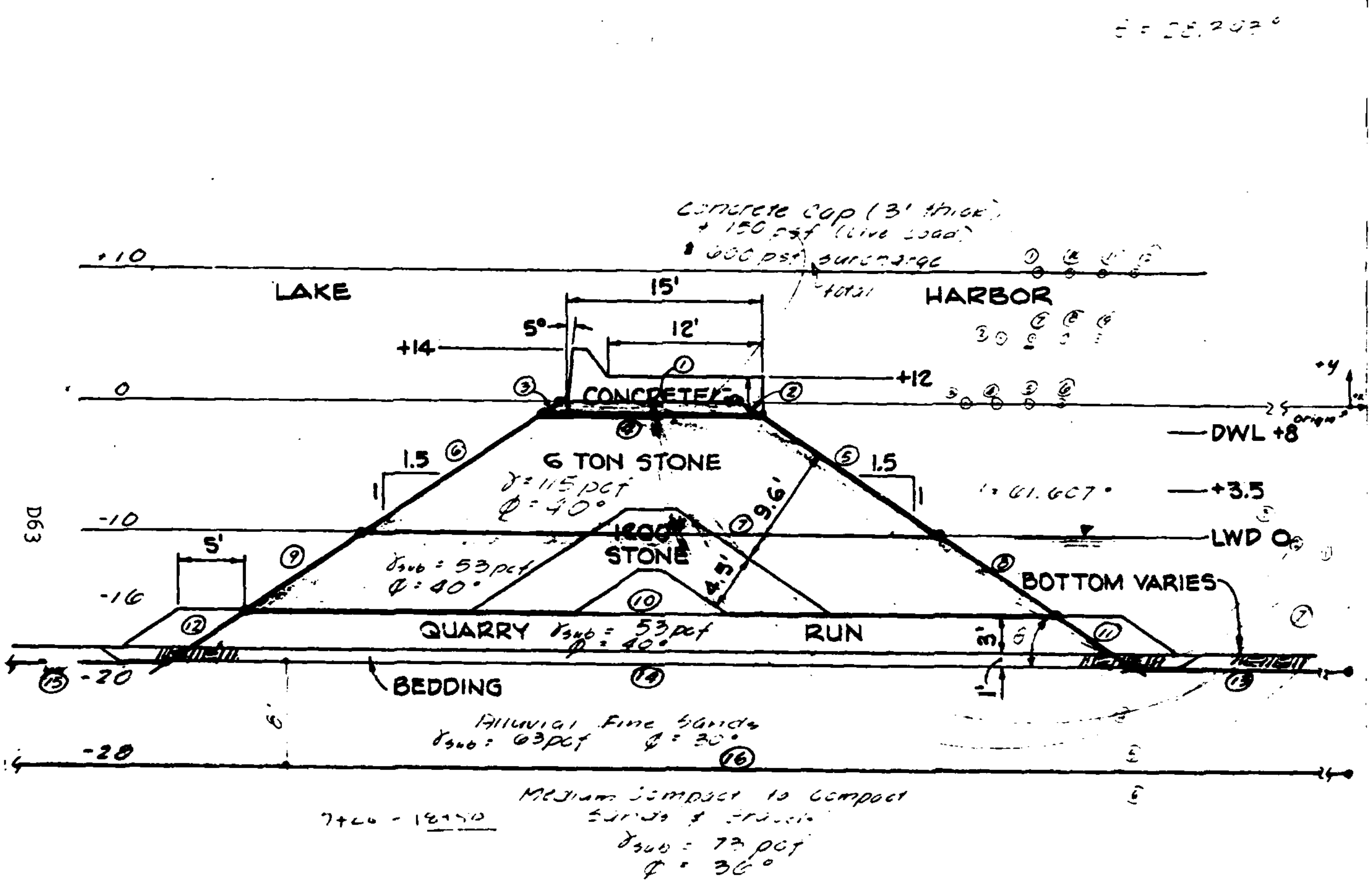
CONCLUDE: ESTIMATED SETTLEMENT 2 - 3 INCHES.

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT C. of E.	JOB NO. C-1617	
	PROJECT CATT	SHEET OF	
	CALCULATIONS FOR slope stability	DESIGNED BY DOI	DATE 9-75
		CHECKED BY AO/WB	DATE 12-75

Line	X1	Y1	X2	Y2	W γ pcf	F tanϕ	C psf	U
1	-100.	0	-114.	0	600	0	0	1
2	-98.5	-1.	-100.	-1.	600	0	0	1
3	-114.	0	-115.5	-1.	600	0	0	1
4	-98.5	-1	-115.5	-1	115	.839	0	1
5	-85.	-10	-98.5	-1	115	.839	0	1
6	-115.5	-1	-129.	-10	115	.839	0	1
7	-85.	-10	-129.	-10	53	.839	0	1
8	-76.	-16	-85.	-10	53	.839	0	1
9	-129.	-10	-138.	-16	53	.839	0	1
10	-76.	-16	-138.	-16	53	.839	0	1
11	-70.	-20	-76	-16	53	.839	0	1
12	-138.	-16	-144.	-20	53	.839	0	1
13	0.	-20	-70.	-20	63	.577	0	1
14	-70.	-20	-144.	-20	63	.577	0	1
15	-144.	-20	-200.	-20.	63	.577	0	1
16	0.	-28	-200.	-28	73	.726	0	1

Center of Assumed Failure Arc (Thru Center of COP -107, 10)

Arc	X	Y	R	F.S.	
1	-77.69	10.	30.969'	1.153	
2	-80.39	5.	27.076'	1.138	
3	-83.09	0.	23.91'	1.161	
4	-80.59	0.	26.41'	1.162	
5	-78.09	0.	28.91'	1.284	
6	-75.59	0.	31.41'	1.354	
7	-77.89	5.	29.539'	1.118	← Minimum
8	-75.39	5.	32.003'	1.171	
9	-72.89	5.	34.470'	1.326	
10	-75.19	10.	33.345'	1.127	
11	-72.69	10.	35.738'	1.175	
12	-70.19	10.	38.144'	1.302	



LAKE
HARBOR
15'
12'
5°
+14
+12
+10
0
-10
-16
-20
-28
CONCRETE
6 TON STONE
1200# STONE
QUARRY RUN
BEDDING
BOTTOM VARIES
DWL +8
+3.5
LWD 0
1.5
1
5'
9.6'
4.5'
Concrete cap (3' thick)
+ 150 psf (live load)
Alluvial Fine Sands
Medium compact to compact

BERM

GENERAL

D30. The shore end of the north breakwater terminates on a sand spit which has been shown in Appendix B to change configuration under the influence of creek discharge and wave conditions. A channel was breached across the spit in 1971 when ice jammed the mouth of the creek. The ice jam created a backwater which overtopped the spit and eroded a new channel north of the present creek mouth. Construction of the breakwaters should reduce the probability of an ice jam occurring. The spit has a crest elevation of +8 feet LWD, which coincides with the design water elevation. The integrity of the spit would be threatened by flood-induced scour tending to undermine the north breakwater terminus. Beach erosion and wave runup could also breach the spit from the lakeward side. A riprap berm is designed to connect the breakwater terminus to the higher sand berms to the north. The riprap should be stable against wave attack from the lake side and scour from the creek side.

DESIGN

D31. The berm was designed to connect the north breakwater to higher and more stable ground to the north. The berm alignment, shown in Plate 1 and Figure D16, is oriented on a 27-degree azimuth. The berm is connected to the breakwater with a rounded corner as opposed to a sharp corner. The corner was rounded to reduce vulnerability of the armor units and toe to erosion and scour. The berm extends 550 feet from the breakwater over a sand spit to a natural berm with elevation higher than 12 feet LWD. The crest elevation was selected at 11 feet LWD. This elevation would result in minor and infrequent wave overtopping.

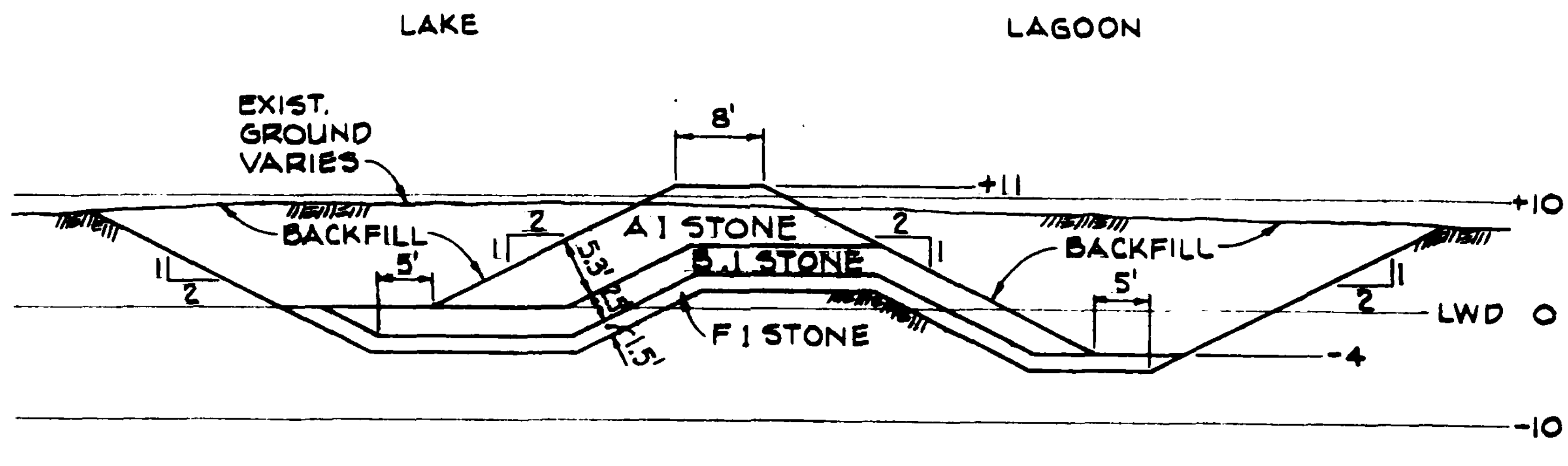
D32. The berm is armored on the lake side to protect against waves and on the creek side to protect against erosion by boat wakes, overtopping waves, and creek shear stress. The berm is located 100 feet shoreward from the lake. The analysis of erosion presented in

Appendix B indicated that 100 feet of beach could erode within two years of low-sediment discharge or inadequate maintenance. The lake side of the berm is riprapped with 1-ton armor stone. The armor extends to a depth of LWD, as shown in the cross-section in Figure D27. The side slope of 1:2 was selected to be the minimum slope which would be stable over the loosely compacted sand-and-gravel spit. The armor stone is to be randomly placed in two layers. The 1-ton stone should be stable for a 6-foot wave breaking at the toe of the structure. The 1-ton stone has a 200-pound underlayer stone. The underlayer extends 5 feet beyond the armor to provide a toe protection. A considerable amount of excavation and backfill will be required to construct the berm to place the toes deep enough to protect from scour. It will be necessary to backfill the area left by the construction of the berm for safety and water-quality purposes.

D33. The design criteria required for the creek side of the berm are not as clearly defined as for the lakeward side of the berm or for a conventional channel lining. The hydraulics of the side channel flow cannot be accurately calculated with the limited topographic data available. A 200-pound stone placed in a 2.5-foot-thick layer was selected for design. This stone is required for the 1-ton armor underlayer. The 200-pound stone would be stable against a 2.5-foot boat wake and a 13.8 fps river current. Calculations are shown in Paragraph D36. The cross-section in Figure D27 shows the riprap extending to a depth of -4 feet LWD. This depth was selected based on the existing depth in the side channel of -4 feet LWD. Approximately 30,000 cubic yards of sand must erode prior to the channel side of the berm being subjected to design forces.

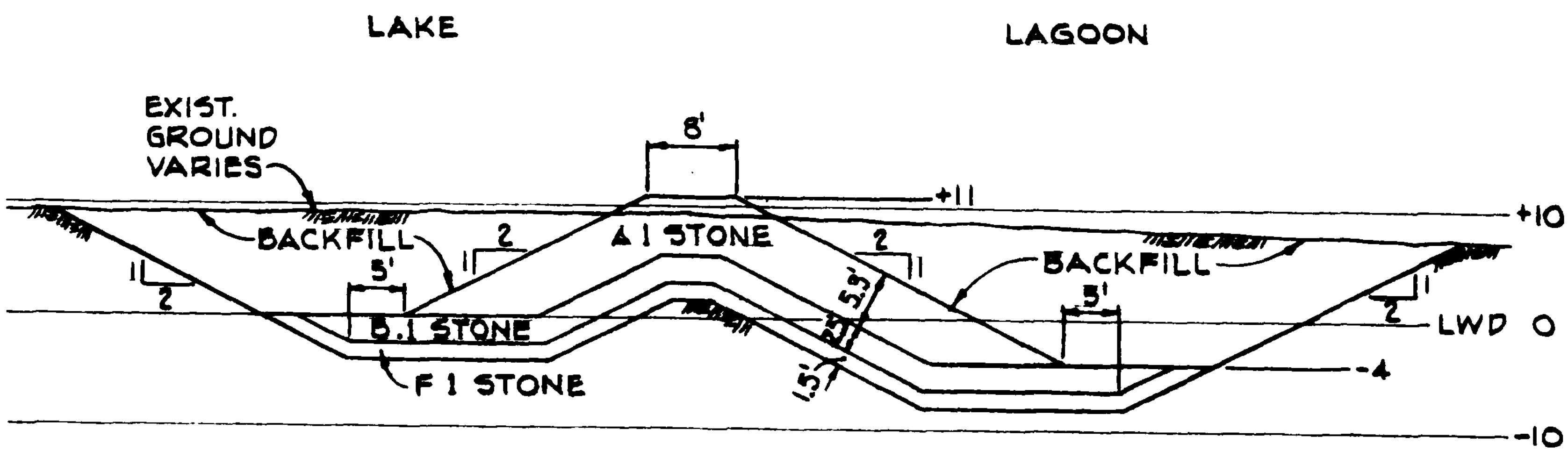
D34. The corner where the berm transitions to the breakwater may be subjected to greater shear forces than the trunk section. The corner will also be more exposed to wave action than the trunk section. Figure D28 shows the rounded corner designed using 1-ton armor on both the lake and creek sides.

D35. The berm is to be constructed over a sand-and-gravel spit. Water level differentials caused by wave overtopping or possibly by backwater could result in the base



BERM
STA. 1+00 TO STA. 5+50
SCALE: 1" = 15'

FIGURE D27



BERM

STA. 0+00 TO STA. 1+00

SCALE: 1" = 15'

FIGURE D28

material washing through the structure. A filter material is to be placed under the 200-pound stone. The filter material may be a stone product or a plastic filter cloth. The design is based on use of a stone filter layer.

D36. Berm Calculations.

1. Runup (Page D69)

2. Armor Stone (Pages D69-D70)

3. River Riprap (Pages D71-D72)

4. Filter Requirements (Page D72)

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BED	JOB NO	
	PROJECT Cattaraugus Creek	SHEET 1 OF 4	
	CALCULATIONS FOR BERM DESIGN	DESIGNED BY KW	DATE 10-21-75
		CHECKED BY WB	DATE 12-75

RUN UP

assume $H_0 = 12'$

$T = 7.8$ Sec

slope (composite) = 1:20
conservative - actual slopes are flatter.

$$\frac{H_0}{gT^2} = \frac{12}{g\,7.8^2} = .0061$$

$$R/H_0' = .24 \qquad \text{Fig 7-11 SPM}$$

$$R = .24 \cdot H_0' = 2.9'$$

$$= 2.9 + 8 = \underline{10.9' \text{ LWD}}.$$

8' LWD beach presently over topped
long term storm berm to +12 to +15' on beaches to the north

rec. 11 ft berm - infrequently over topped.

11' LWD > Breakwater crest at +10' LWD

armor stone

Design wave indeterminate since berm is located on beach
select $H_b = 6'$

1:2 slope (over loose gravel)

$\gamma_r = 165$

$K_a = 3.5$ breaking wave - random placement 2 layer

$$W = \frac{\gamma_r H^3}{K_a \cot\alpha \left(\frac{\gamma_r}{\gamma_w} - 1\right)^3}$$

$$= \frac{165 \cdot 6^3}{3.5 \cdot 2 \cdot \left(\frac{165}{62.4} - 1\right)^3} = 1145 \text{ lb.}$$

select 1 TON armor

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BEO	JOB NO.	
	PROJECT CaTT.	SHEET 2 OF 4	
	CALCULATIONS FOR BERM	DESIGNED BY KW	DATE 10-21-75
		CHECKED BY WB	DATE 12-75

Thickness

$$r = 1.15 \cdot 2 \left(\frac{2000}{165}\right)^{1/3}$$

$$= 5.3'$$

Gradation

$W_{max} = 4000$ Lb

$W_{50} = 2000$ Lb

$W_{min} = 1500$ Lb.

Crest width

$B = 3$ Dia.

$= \frac{3}{2} r = 8.0'$

underlayer

$$W_u = \frac{W_{50}}{10} = 200 \text{ Lb.}$$

Gradation

$W_{max} = 400$ Lb

$W_{50} = 200$ Lb

$W_{min} = 100$ Lb

thickness

$$r = 1.15 \cdot 2 \cdot \left(\frac{200}{165}\right)^{1/3}$$

$$= 2.5'$$

River rip rap

MIN. required for 2.5' boat wake

$$W = \frac{\gamma H^3}{K_a \cdot \cot\alpha \left(\frac{165}{62.4} - 1\right)^3}$$

= 83 Lb.

∴ 200 Lb. stable

Same thickness and gradation as armor underlayer on lake side

spherical diameter

$$D = \left(\frac{6W}{\pi \gamma}\right)^{1/3}$$

$$= \left(\frac{6 \cdot 200}{\pi \cdot 165}\right)^{1/3}$$

$= 1.3'$

river velocity 200 Lb is stable on:

$$\tau_a = .04(165 - 62.4) D_{50} \qquad \text{EM 1110-2-1601}$$

$$= 5.33 \qquad \text{EQ 33}$$

$$\frac{\tau_{side}}{\tau_a} = \left(1 - \frac{\sin^2\phi}{\sin^2\theta}\right)^{1/2} \qquad \text{EQ 34}$$

$$= \left(1 - \frac{\sin^2 26.6}{\sin^2 40}\right)^{1/2} \qquad \phi = \tan^{-1} .5 = 26.6°$$

$= .72$

$\tau_{as} = .72(5.33) = 3.82$

$$\tau = \frac{\gamma V^2}{\left(32.6 \log \frac{12.2\, d}{D_{50}}\right)^2} \qquad \text{EQ 32.}$$

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT CED	JOB NO.	
	PROJECT CATT.	SHEET 4 OF 4	
	CALCULATIONS FOR BERM	DESIGNED BY KW	DATE 10-21 75
		CHECKED BY WB	DATE 12 75

$d = -4 \text{ LWO} + 2' = 6$

$$\tau = \frac{62.4 V^2}{\left(32.6 \log \frac{12.2 \cdot 6}{1.3}\right)^2}$$

$$\tau = .02 V^2$$

$$\tau_a = 3.82 = .02 V^2$$

$$\bar{V} = \sqrt{\frac{3.82}{.02}} = 13.8$$

hence stone should be stable for $\bar{V} \le 13.8$ FPS excluding bend enhanced shears

FILTER requirement

Plastic Filter cloth or stone acceptable

Base Material loose sand - gravel

see Figure C7 for Base material from TP-75-1

$D_{15A} \approx 250$ mm $\quad \frac{D_{15A}}{D_{85F}} = 3.1$

$D_{85F} = 80$ mm $\quad \le 5$ ok

select Filter as shown in FIG. C7

Filter to Base adequate by inspection of FIG C-7

CHANNELS

GENERAL

D37. The primary purpose of the channel is to provide navigation benefits with some flood control benefits. The proposed channel alignment is shown in Plate 1. The channel is 5,000 feet long, terminating downstream from the Penn Central Transportation Company bridge. The channel entrance is 200 feet wide and has an 8-foot depth of water during navigation, or a -5.5-foot LWD project depth. The width was selected based on maneuvering room requirements for boats entering the harbor. The -8-foot channel depth was selected as a minimum to meet the requirements of small-boat navigation. The channel width is decreased to 100 feet in the straight portion of the more protected upstream area. The channel depth is decreased for reaches upstream from the river mouth. Boats currently using the creek navigate in depths of 3 to 5 feet of water. The improved channel is to be maintained to a depth of water of 6 feet. This differs from the project document and Phase I General Design Memorandum plan which had a -6-foot LWD depth. The requirement for maintaining 6 feet of water depth results in less initial dredging and a lower annual maintenance. This topic is discussed in greater detail in Appendix B, Impacts on Littoral Drift. The design philosophy contends that the channel bottom rises and lowers with the long-term lake level changes, thereby maintaining a relatively constant water depth. Dredging a channel to -6 feet LWD with a +4-foot LWD lake level would create a more efficient sediment trap than maintaining a channel to a lesser depth.

PROJECT CHANNEL DEPTH

D38. Selection of the project depth was based on the 1975 creek soundings which were taken at a +4.1-foot LWD lake stage. A 1.5-foot decrease in lake level was estimated as a typical seasonal fluctuation resulting in a stage of +2.6 feet LWD during the summer and fall. A project depth of -3.5 feet LWD results in a 6-foot navigation channel. The entrance channel requires a

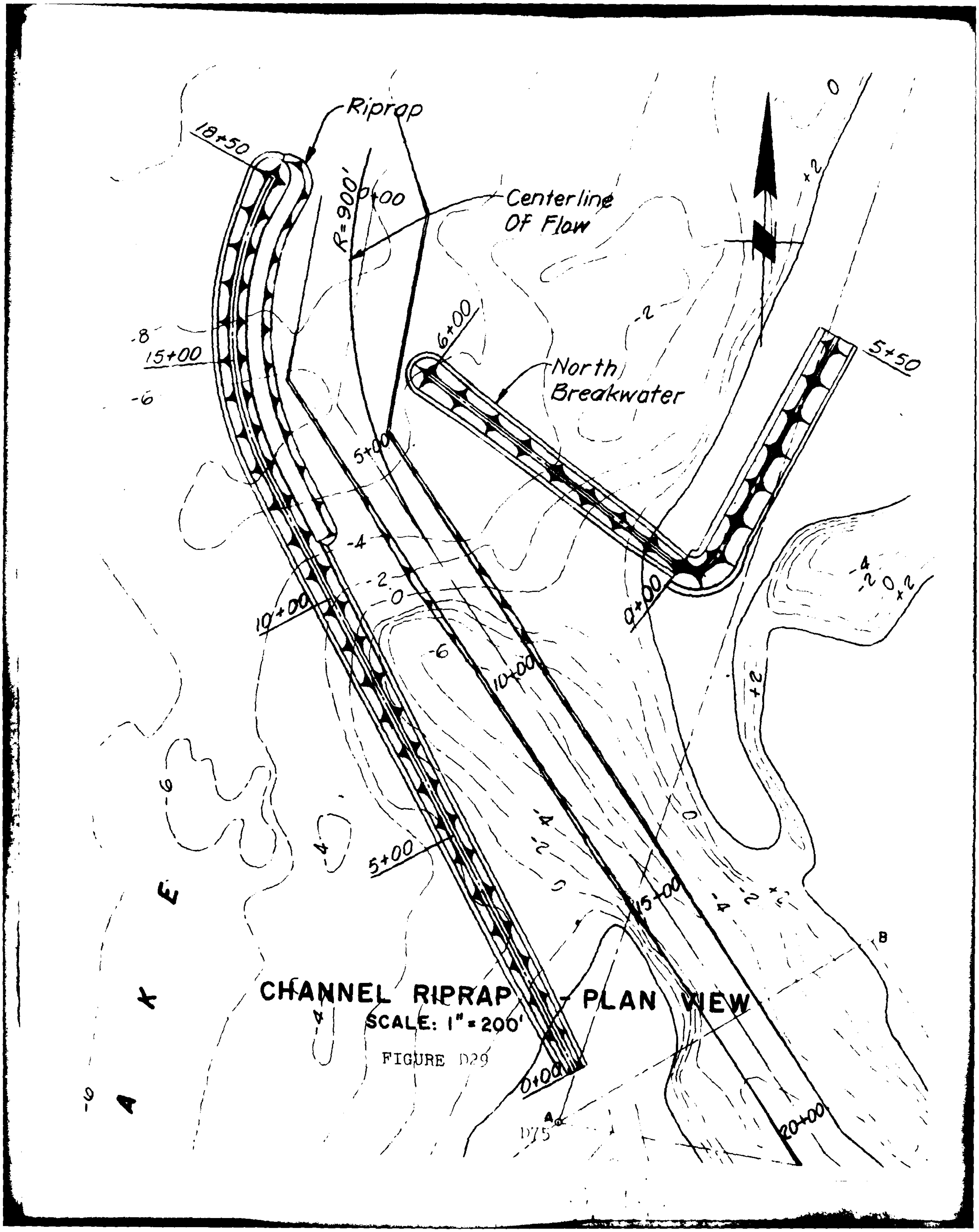
2-foot greater depth allowing for greater wave action. One foot of over-dredge was assumed for all channel reaches in estimating quantities of dredged material. Dredged material comprises a silt-and-sand veneer overlying a sand-and-gravel bed. No bedrock is anticipated to be excavated. The channel side slopes for the sand and gravel will be stable at 2 horizontal to 1 vertical. The project depth will fluctuate with long-term lake level fluctuations; however, the depth of water for navigation should remain relatively constant.

RIPRAP

D39. The primary purpose of the channel is for navigation improvements. The channel is to be excavated near the centerline of the creek. Due to sediment discharge, it will be difficult to maintain the planned channel alignment. The deep part of the channel will continue to meander as indicated in Figure B4. Dredging the channel should tend to stabilize the bottom during moderate discharges. The navigation channel should convey a greater proportion of flow and reduce shear stresses on the side banks. Some areas presently eroding may continue to erode; however, construction of the channel should not generally aggravate bank erosion.

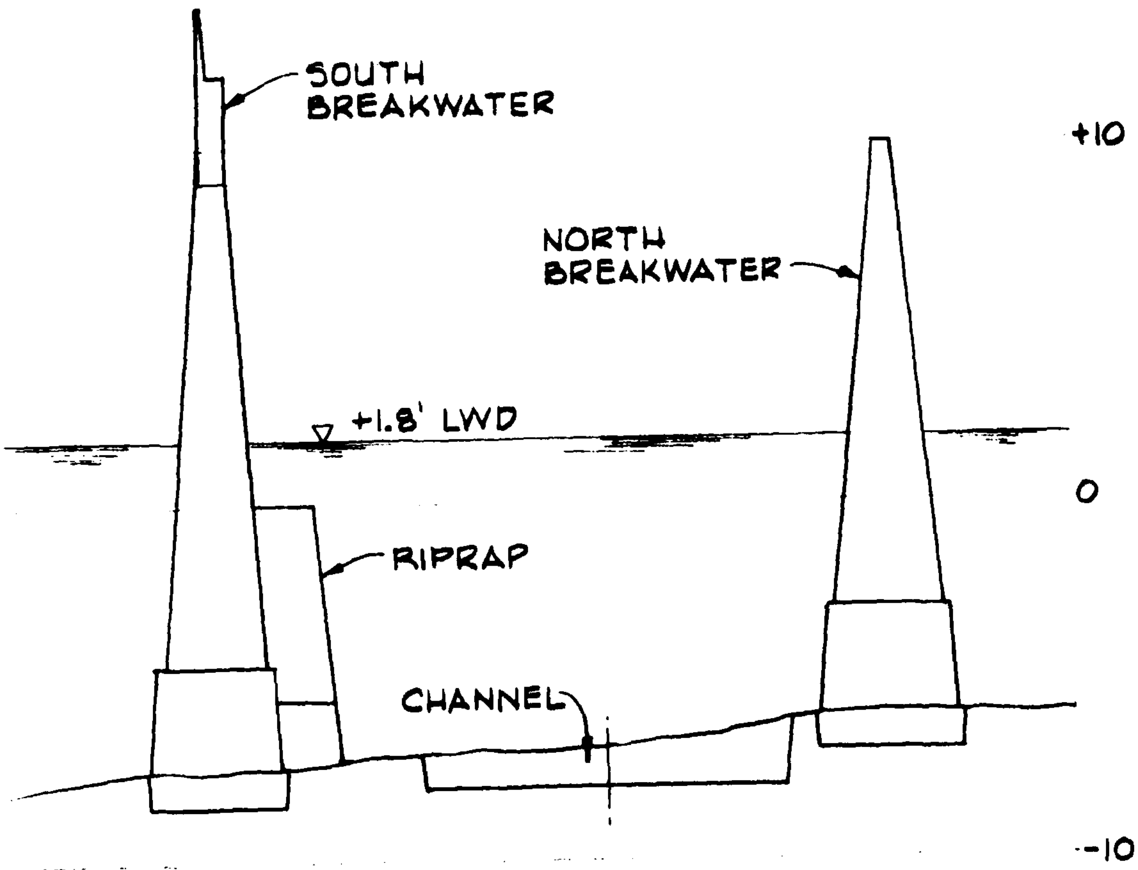
BREAKWATER TOE PROTECTION

D40. The creek channel at the harbor entrance is diverted northward abruptly, as shown in Figure D29. Current-induced shear stresses are increased on the outer banks of curved channels. The increased shears tend to scour a deeper channel on the outer bank. Riprap protection is required to stabilize the outer bank from scouring the heel of the south breakwater. The design flow for flood control purposes of 30,000 cfs has a 6-year recurrence period. The 20-year recurrence structural design flood is 40,000 cfs. This flow is assumed to enter the lake during an average lake level of +1.8 feet LWD. Figure D30 shows a section taken through the entrance channel. The mean channel velocity for a 40,000-cfs discharge is 13.1 fps. The



CHANNEL RIPRAP - PLAN VIEW
SCALE: 1" = 200'

FIGURE D29



CHANNEL SECTION
FOR RIPRAP PROTECTION

SCALES: HOR. 1" = 100'
VERT. 1" = 5'

FIGURE D30

assumed centerline radius of the flow is 900 feet, and the channel width is 300 feet. Shear stresses are increased by a factor of 1.79 on the outer bank. A 5.5-foot layer of 1/2-ton stone placed over a filter is required to stabilize the channel. Riprap and filter calculations are presented in Paragraph D41. Figure D31 shows a typical section. The berm width of 40 feet was selected to allow for settlement to a 1:2 slope during a major flood. Riprap is required from Station 11+00 to the head section. The channel may meander in time. The channel may align to become parallel to the south breakwater. Should this occur, additional riprap protection may be required to line the south breakwater. This is not considered likely and is, therefore, not included in the initial design.

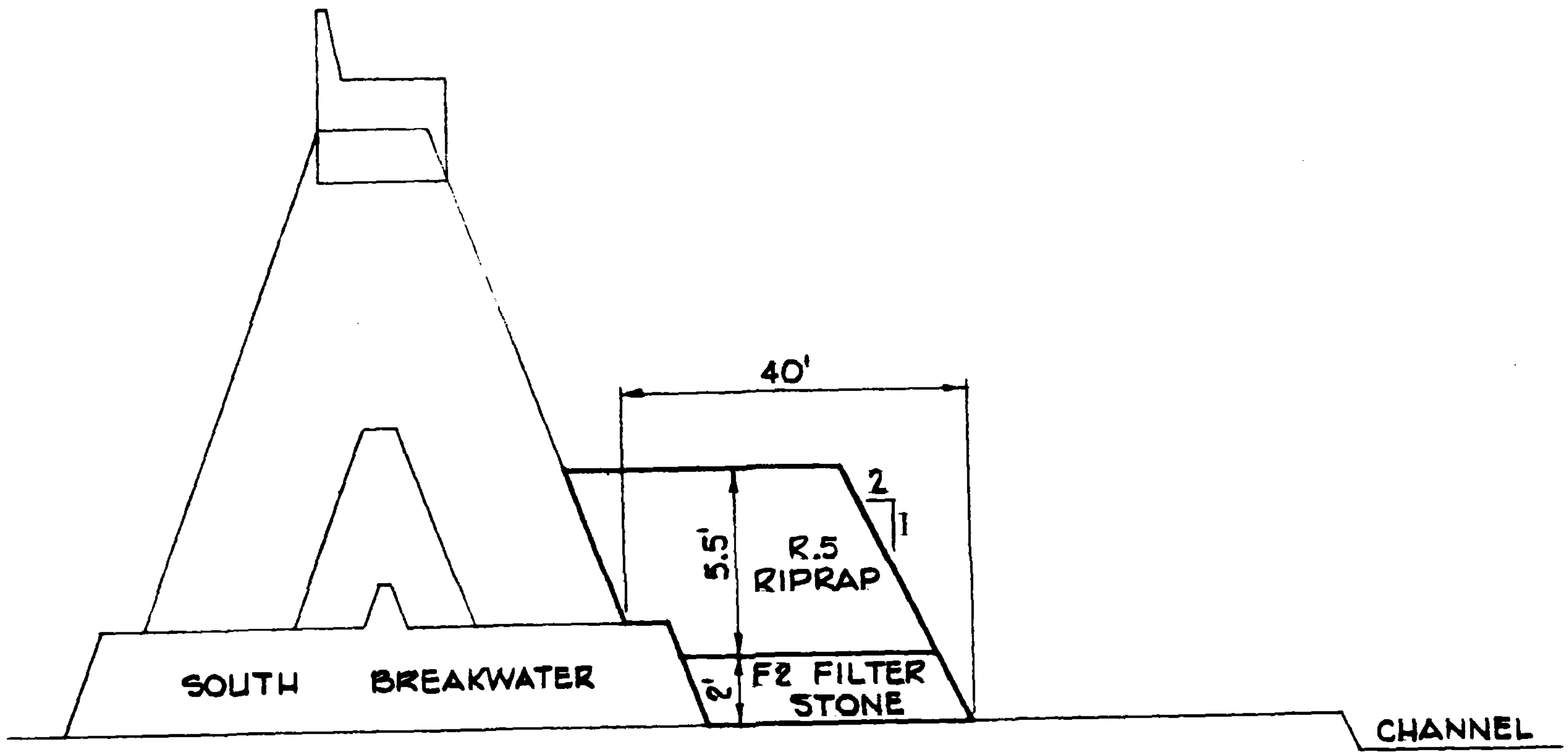


FIGURE D31

CHANNEL RIPRAP

SCALES: HOR. 1" = 20'
VERT. 1" = 5'

D41. Channel Riprap Calculations.

1. Design Shears (Pages D80-D81)
2. Stable Riprap (Page D81)
3. Armor Placement (Page D82)
4. Gradation (Page D82)
5. Filter (Page D83)
6. Filter Placement (Page D84)
7. Scour Potential (Page D84)

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT DED	JOB NO	
	PROJECT CUTT.	SHEET 1 OF 5	
	CALCULATIONS FOR CHANNEL RIPRAP	DESIGNED BY KW	DATE 10-24-75
		CHECKED BY WB	DATE 12-75

DESIGN Shears

$Q = 40{,}000$ CFS - 20 yr design flow

assume Lake Level ave. annual 1.8' LWD

AREA between breakwater - channel

$A = 3050$

$R = 9.27'$

$P = 329'$

$$\bar{V} = \frac{40{,}000}{3050} = 13.1 \text{ FPS}$$

$$\bar{\tau}_0 = \frac{\gamma_w \bar{V}^2}{\left(32.6 \log \frac{12.2 R}{k}\right)^2}$$ (EM 1110-2-1601 EQ 31)

$\gamma_w = 62.4$

$V = 13.1$

$R = 9.27$

$k = D_{50}$ $\quad D_{50} \doteq .01'$ - DC-75-1 surf at 10-12'

$\bar{\tau}_0 = 0.613$

radius of curvature of flow approx 900' = r
channel width ≈ 300'

$r/w = 3$

$$\frac{\tau_b}{\bar{\tau}_0} = 3.1\left(\frac{r}{w}\right)^{-.5}$$ (rough channel plate 34 EM 1110-2-1601)

$= 3.1(3)^{-.5}$

$= 1.79$

$\tau = 1.79 \times 0.613 = 1.10$ LB/FT^2

shear exceeds THAT permissible for stable channel

$\tau = .04(\gamma_s - \gamma_w) D_{50}$

$= .04$

hence rip rap protection is required.

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	PROJECT CATT	SHEET 2 OF 5	
	CALCULATIONS FOR RIPRAP	DESIGNED BY KW	DATE 10-20-75
		CHECKED BY WB	DATE 12-75

assume riprap scours to a 2H to 1V slope

Side Slope

$$\tau' = \tau\left(1 - \frac{\sin^2\phi}{\sin^2\theta}\right)^{.5}$$

$\theta = 40°$ (< of repose)

$\tan\phi = .5$

$= 26.6°$

$$\tau' = \tau(1 - .49)^{.5}$$

$$= \tau(.71)$$

stable rip rap - design shear

$$\tau = .04(\gamma_s - \gamma) D_{50}$$

$\gamma_s = 165$

$\gamma = 62.4$

$$\tau = 4.1\ D_{50}$$

$$\tau' = .71(4.1) D_{50}$$

$$= 2.9 D_{50}$$

assume 1/2 TON stone

$$D_{50} = \left(\frac{6W}{\pi \gamma_s}\right)^{1/3} = 2.26'$$

$$\tau' = 2.9 \cdot 2.26 = 6.56$$

$$\tau_o = \frac{\gamma_w V^2}{\left(32.6 \log 12.2 \frac{R}{K}\right)^2}$$

$K = 2.26$

$= 3.49$

$$\tau_b = (3.57)(1.79)$$

$= 6.2$

1000 LB STONE STABLE

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	PROJECT CATT	SHEET 3 OF 5	
	CALCULATIONS FOR RIP RAP	DESIGNED BY KCJ	DATE 10-20-75
		CHECKED BY WB	DATE 12 75

Placement

Place in 2 layers over a filter material

Thickness

Place under water

$t = 1.5\ D_{50u}$ min

increase by 1.5 times for under water

$t = 2.25\ D_{50u}$

$t \geq 1.5\ D_{100u}$

Gradation

	select
$W_{50L} = 1000$ Lb	1000
$W_{100L} \geq 2 \cdot W_{50L} \geq$ 2000 Lb	2000
$W_{100u} \leq 5 \cdot W_{50L} \leq 5000$ Lb	
select $t = 5.5'$	
$D_{50u} = 5.5/2.25 = 2.44$	
$W_{50u} = D^3 \dfrac{\pi \gamma_s}{6} = 1255$	1300
$D_{100u} \leq t/1.5 = 5.5/1.5 = 3.67'$	
$W_{100} \leq 4271$	4000
$W_{15L} \geq W_{100u}/16 \geq 250$	250
$W_{15u} \leq W_{50u}$	1000

Select Gradation with $t = 5.5'$

Percent Lighter by Weight	Limits of Stone Weight Lb.
100	2000 - 4000
50	1000 - 1300
15	250 - 1000

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT CEO	JOB NO
	PROJECT catt.	SHEET 4 OF 5
	CALCULATIONS FOR RIP RAP	DESIGNED BY KW DATE 10-20-75
		CHECKED BY WB DATE 12.75

Filter

$$\frac{D_{15A}}{D_{85F}} = \frac{610\ mm}{X} = 5$$

$$D_{85F} = \frac{610}{5} = 122\ mm$$

evaluate INSITU materials
ref. Geology, soils APPENDIX
Boring D 75-1 B/W site
$D_{85} = 20$ to 8 mm

Filter required

$D_{85\,Filter} = 120\ mm$

$$\frac{D_{15F}}{D_{850}} = \frac{25}{5} = 5$$

Gradation (see curve)

Percent smaller than by weight	Stone size inches	
100	10	-20
85	6	-12
50	1.5	4
15	.5	1

$D_{50\,max}$ = 4" Place 2.25 × 4"

Place 2' thickness

MOFFATT & NICHOL, ENGINEERS LONG BEACH, CALIFORNIA	CLIENT BEW	JOB NO	
	PROJECT CJ74	SHEET 5 OF 5	
	CALCULATIONS FOR RIPRAP	DESIGNED BY KCJ	DATE 10-20-71
		CHECKED BY WB	DATE 12 5

Filter Placement

Place filter t = 2' over exist bottom after Breakwater is constructed

Some minor scour should occur to −10 to −12' LWD prior to placing filter

Place riprap berm on essentially horizontal surface

Potential depth of scour on in situ material

$D_{50} = .01'$ assume grading occurs, loose fines

$D_{50} = 10mm = .033 ft.$

$\tau_b / \tau_o = 1.79$

$V_b = 6$ fps stable for gravel

$\tau_a = .04(\gamma_s - \gamma) D_{50}$

$= .14$

$\tau_{ab} = .14/1.79 = .07$

$$\tau_{os} = .07 = \frac{62.4 V^2}{(32.6 \log 12.2 R)^2}$$

$$V^2 = \frac{Q}{A} = \frac{Q}{PR}$$

Solve for $\bar{R}$

$$.08 \quad \frac{62.4 \left(\frac{40,000}{329 \cdot R}\right)^2}{\left(32.6 \log \frac{12.2 R}{.033}\right)^2}$$

R = 20 Right side = .148
R = 26 " .081
R = 30 " " = .06

≈ 26' max. clear water scour depth (LWD)

Scour should be less − assume to −20

Provide 40' berm which may assume 1:2 slope