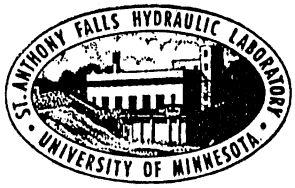
UNIVERSITY OF MINNESOTA
ST. ANTHONY FALLS LABORATORY
Engineering, Environmental and Geophysical Fluid Dynamics

Project Report 379

Hydraulic Study of the Port Superior Marina in Bayfield, Wisconsin

by

Carlos M. Toro-Escobar
and Ben Erickson



Prepared for

R. W. DOCKS & SLIPS
Bayfield, Wisconsin

September 1995
Minneapolis, Minnesota

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Acknowledgments

The authors of this report would like to thank the staff at St. Anthony Falls Laboratory for their help in writing this report. In particular, Dr. Gary Parker, Director, and Richard Voigt, Jr., for their suggestions and opinions. Also we would like to thank Patricia Swanson, editor, for her help with this report. Also we would like to thank Charles Hathaway, et al. from Barr Engineering, Mpls, MN. for their help in completing this report.

Introduction

The St. Anthony Falls Laboratory(SAFL) was contracted to review sedimentation patterns at Port Superior Marina in Bayfield, Wisconsin. A literature review was conducted to study the sedimentation problem. In addition to looking at the sediments, it became necessary to review bay evolution, breakwater characteristics, and ice effects in order to better assess the entire situation.

Barr Engineering will produce a separate report detailing the macrophyte growth characteristics.

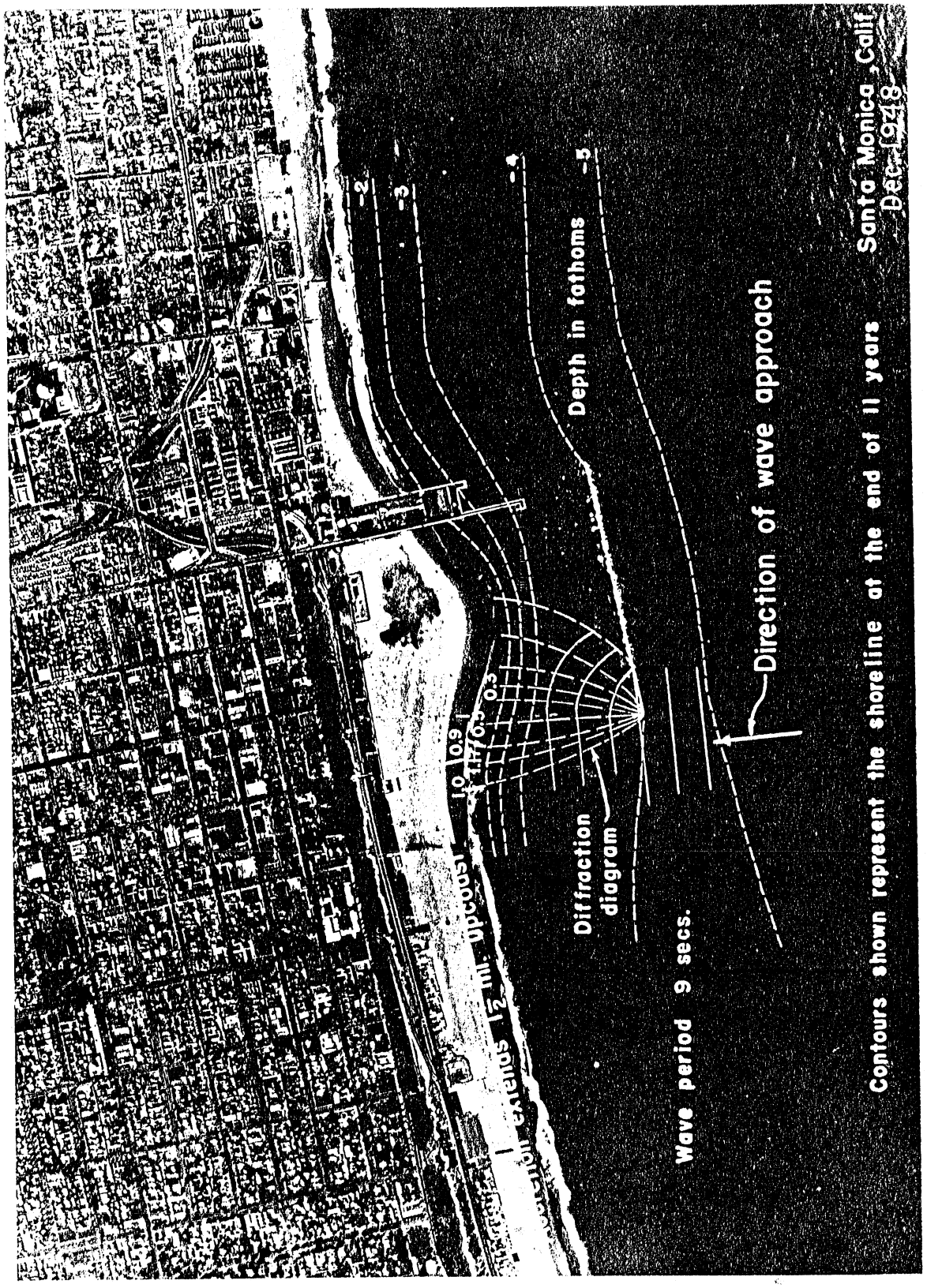

Figure 1 Breakwater effects

Sediment transport characteristics

According to the grain size analysis made inside the breakwater, the material deposited on the bay have a median size around 0.3 mm for almost all the materials in the range of fine sand to silt (Figure 2). On the other hand, just by simple observation and comparison, the material outside the breakwater is definitely coarser than the material inside, which consists of mostly coarse sand.

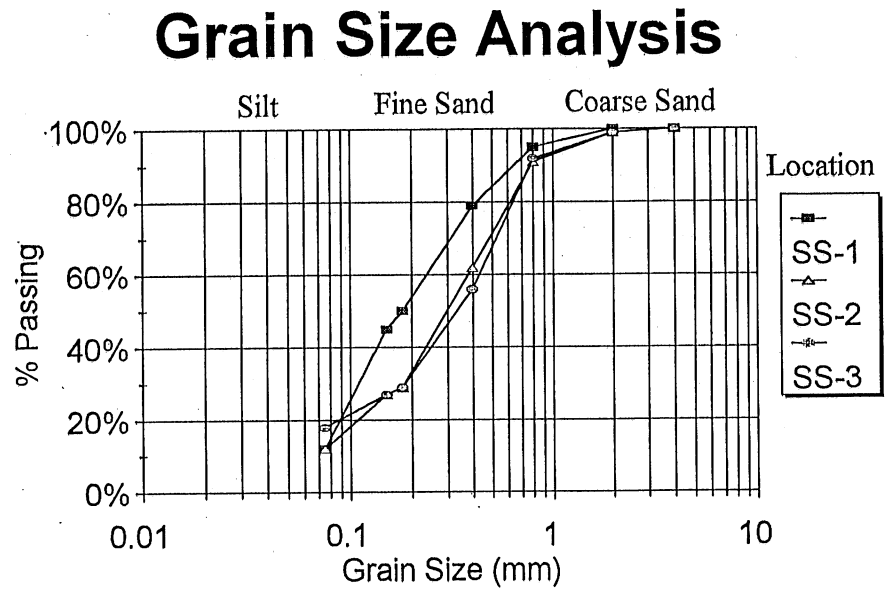

Figure 2 Grain size analisys

By hypothesizing the sediment size deposited at the bottom of the bay both outside and inside the breakwater, we can calculate the hydraulic characteristic of the bay by using the following approach:

1. Given conditions: Water depth, grain size
2. Equations: Sediment transport: $q^* = 8\,(\tau^* - 0.047)$ (Meyer Peter and Muller, 1948)

   Shear stress: $\tau^* = C_f U^2/(gRD)$

   Friction factor: $C_f = \left(2.5 \ln\left(\frac{11H}{k_s}\right)\right)^{-2}$ (Keulegan, s resistance relation)

   where q^* is the dimensionless sediment discharge per unit width, τ^* the dimensionless shear stress, U the mean flow velocity, g the acceleration of the gravity, R the submerge specific gravity of the sediment (R=1.65 for sand), D the particle size, C_f the friction factor, k_s the bed roughness, and H the flow depth.
3. Assumptions: For sediment motion $q^*>0$ (critical velocity)
   Particle size range from 0.05mm to 2mm.
   Water depth variation from 0.1m to 2m.

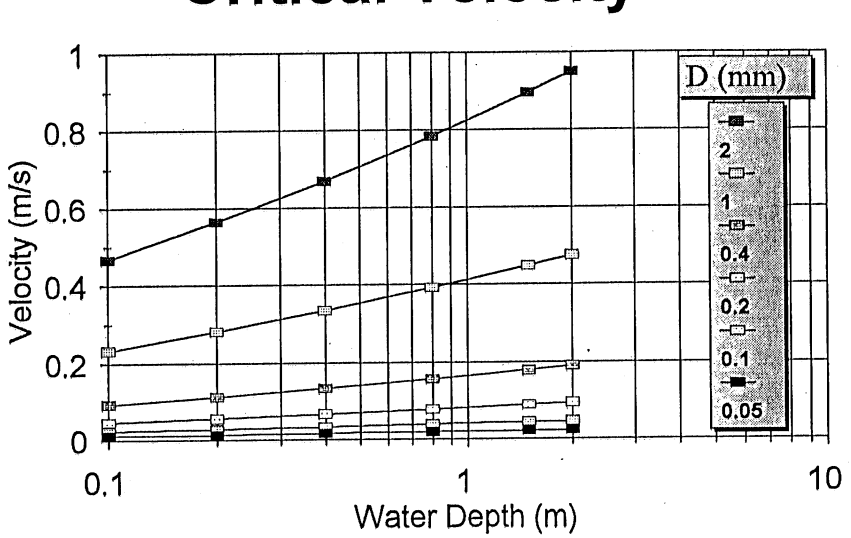

Figure 3 Critical velocity

From this figure we can conclude that inside the breakwater velocities are on the order of 0.2 m/s or less, to keep the fine material there, while those outside of the breakwater are at least on the order of 0.5 to 1.0 m/s in order to move the coarse sand in that region of the bay.

Based on this analysis, the breakwater is working as a true protection measure, keeping the rough waters out of the marina area and preventing the sediment discharged from the creek from filling up the marina.

Ice effects over shoreline

Abrasive action of moving ice.

When an ice pack is moving either during breakup or wintertime, the floes may come in close contact with the shore, wharves, piers, retaining walls or dams and may cause abrasion of the structures at the water level. Deep cuts in a wall, of the order of 0.3 m., have brought about the collapse of a wharf (Korzhavin, 1962). Piles have been cut in less than five or six hours (Kirkham, 1927). During a spring breakup, concrete walls were locally eroded to a depth of about 2 to 8 cm (Telechev et al. 1961).

The erosion of river and lake shores by moving ice is well known and is much more severe in colder climates than scouring action by water alone. Even rock banks are eroded by

ice. One of the main drawbacks of shore protection with boulders, artificial blocks, sand bags, etc... is their poor resistance to ice abrasion (Michel, 1978)

Ice pile-ups on structures

A moving ice field may, under the action of currents, waves and wind, hit the shore of a lake or river and any engineering work located there. It will then induce important ice accumulations while slowing down, and dissipating its energy by breaking and accumulating small ice pieces on its edge. Large size accumulations have been reported in the literature and one close to 30 m. high has been observed by Estifeev (1958).

This accumulation may have harmful effects on the shore because the extra weight increases the abrasive effect underneath the ice.

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Meyer-Peter, E. and Muller, R. (1948). "Formulas for bedload transport". *Proc. 2nd Congress*, International Association of Hydraulic Research, Stockholm, pp. 39 - 64.

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Telechev, V.I., Pinigrin, M.I. and Tolokno, V.V. (1961). "Flow of Ice Through Mamakavskoi Hydroelectric Works". *Hydraulic Constructions*, No. 7.

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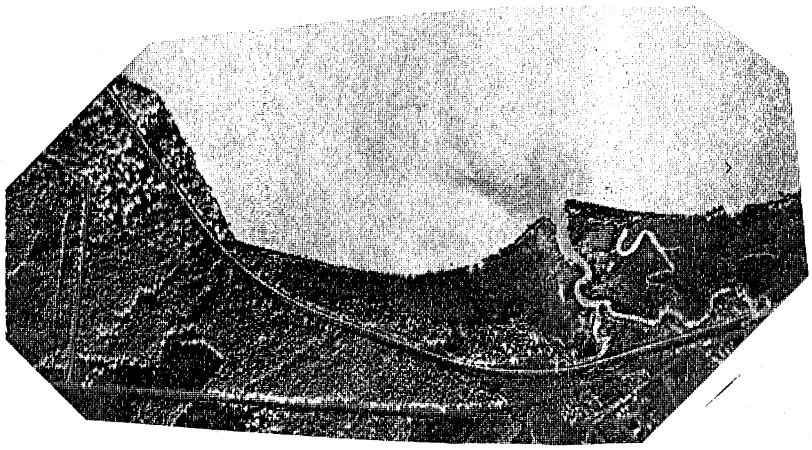
APPENDICES

A. Historical photographs
B. Breakwaters
C. Gradation report

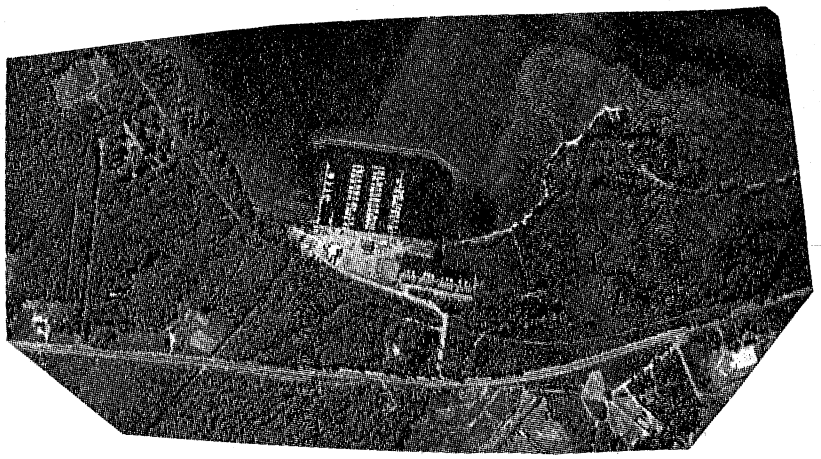
APPENDIX A

Historical photographs



Aerial Photograph 1951

Aerial Photograph 1966



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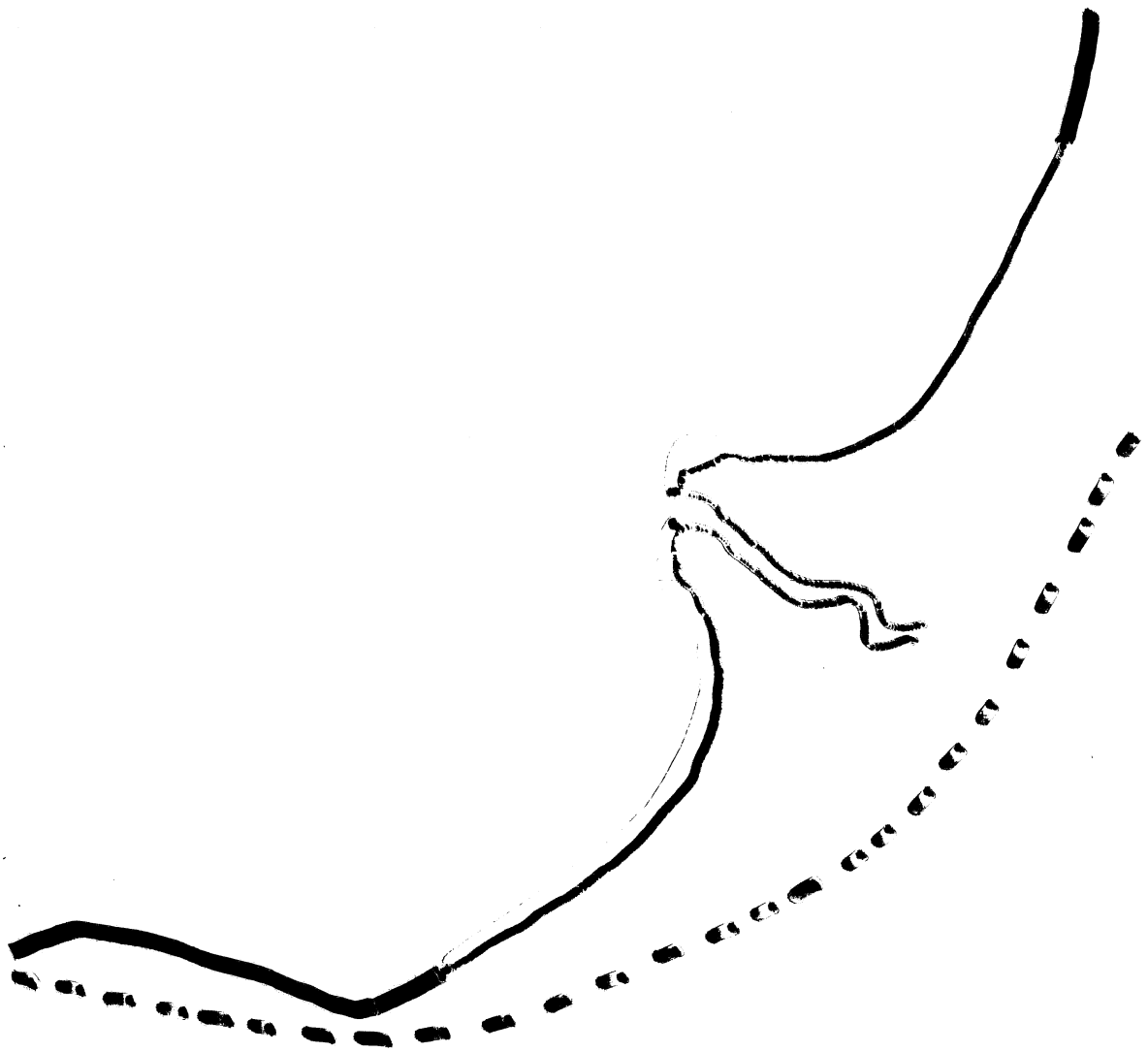
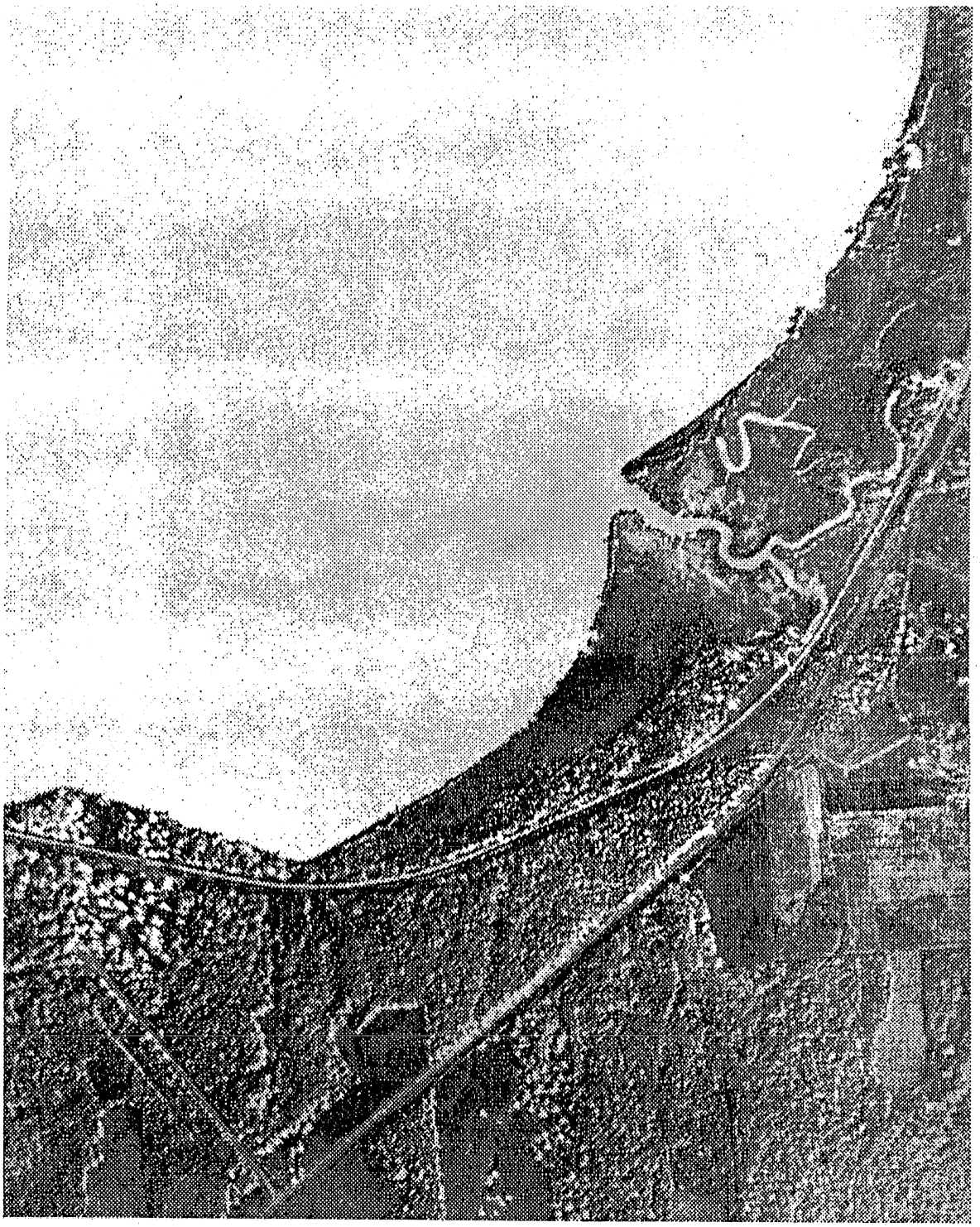
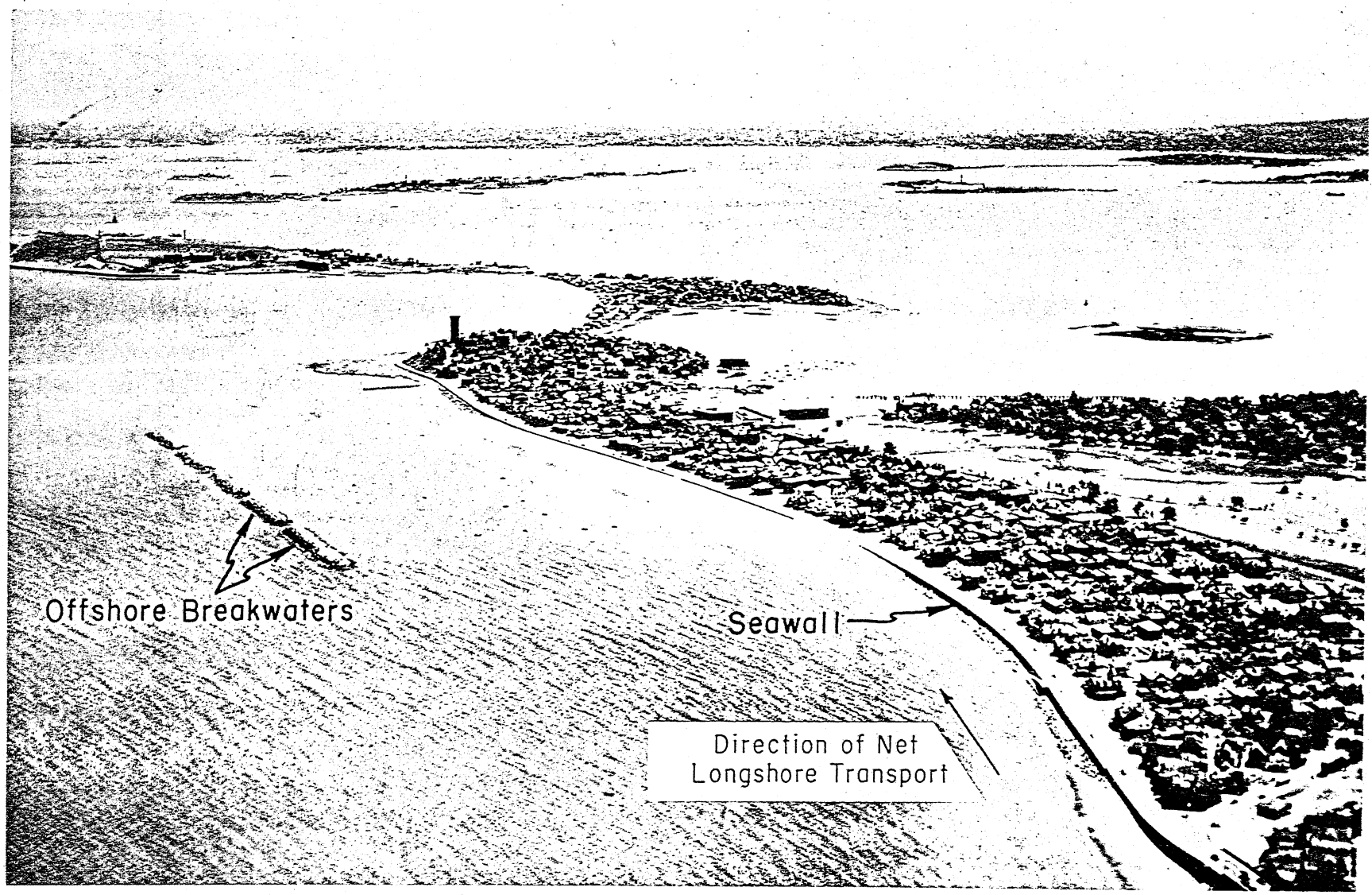




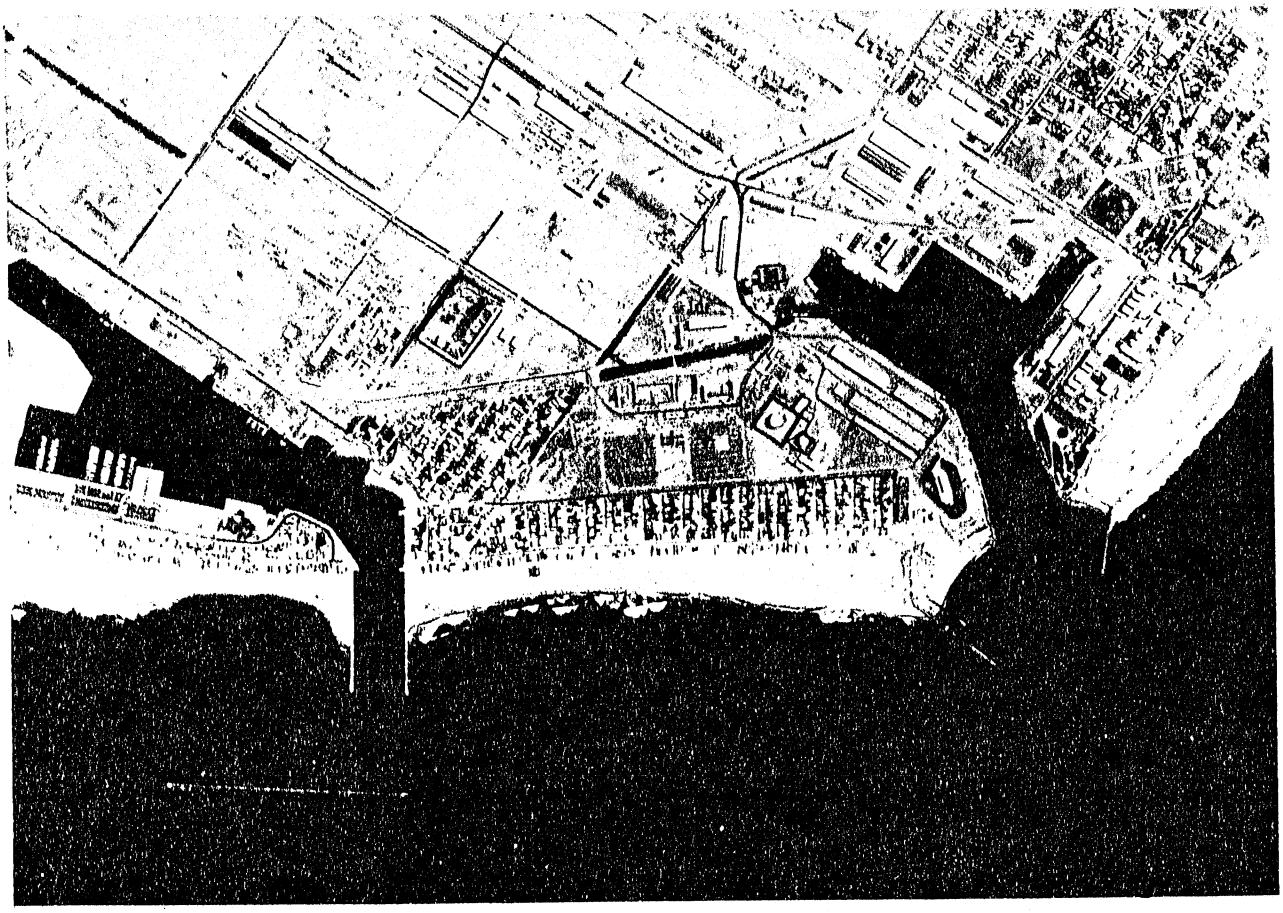
APPENDIX B

Breakwaters

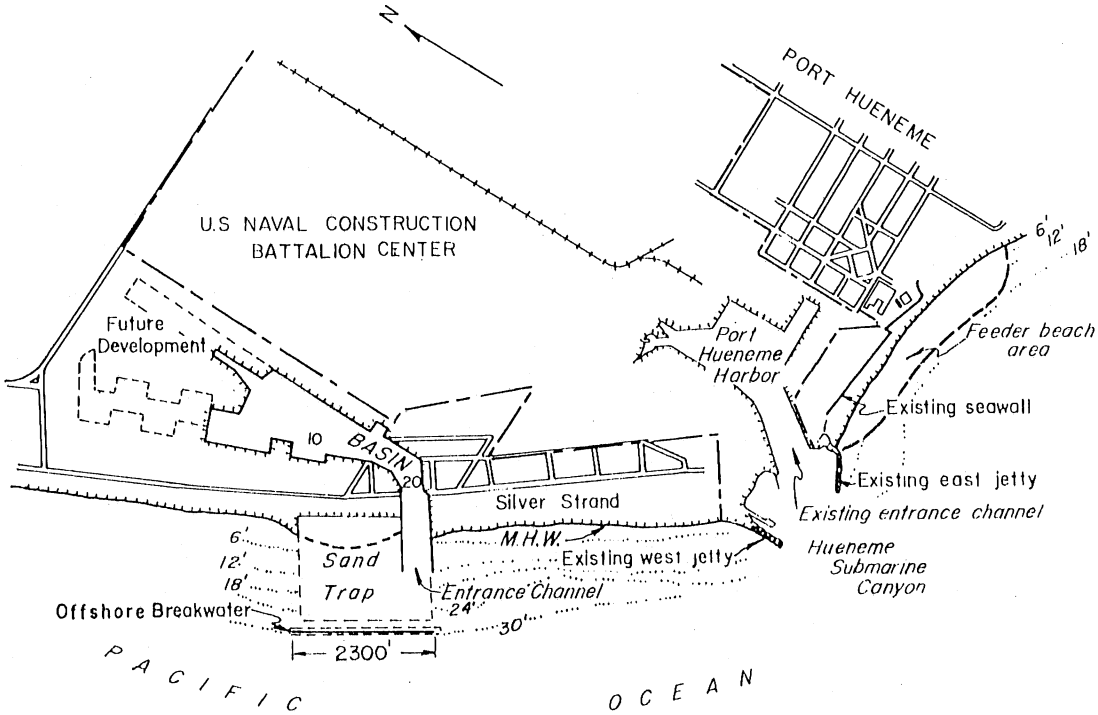


Winthrop Beach, Massachusetts - 1949

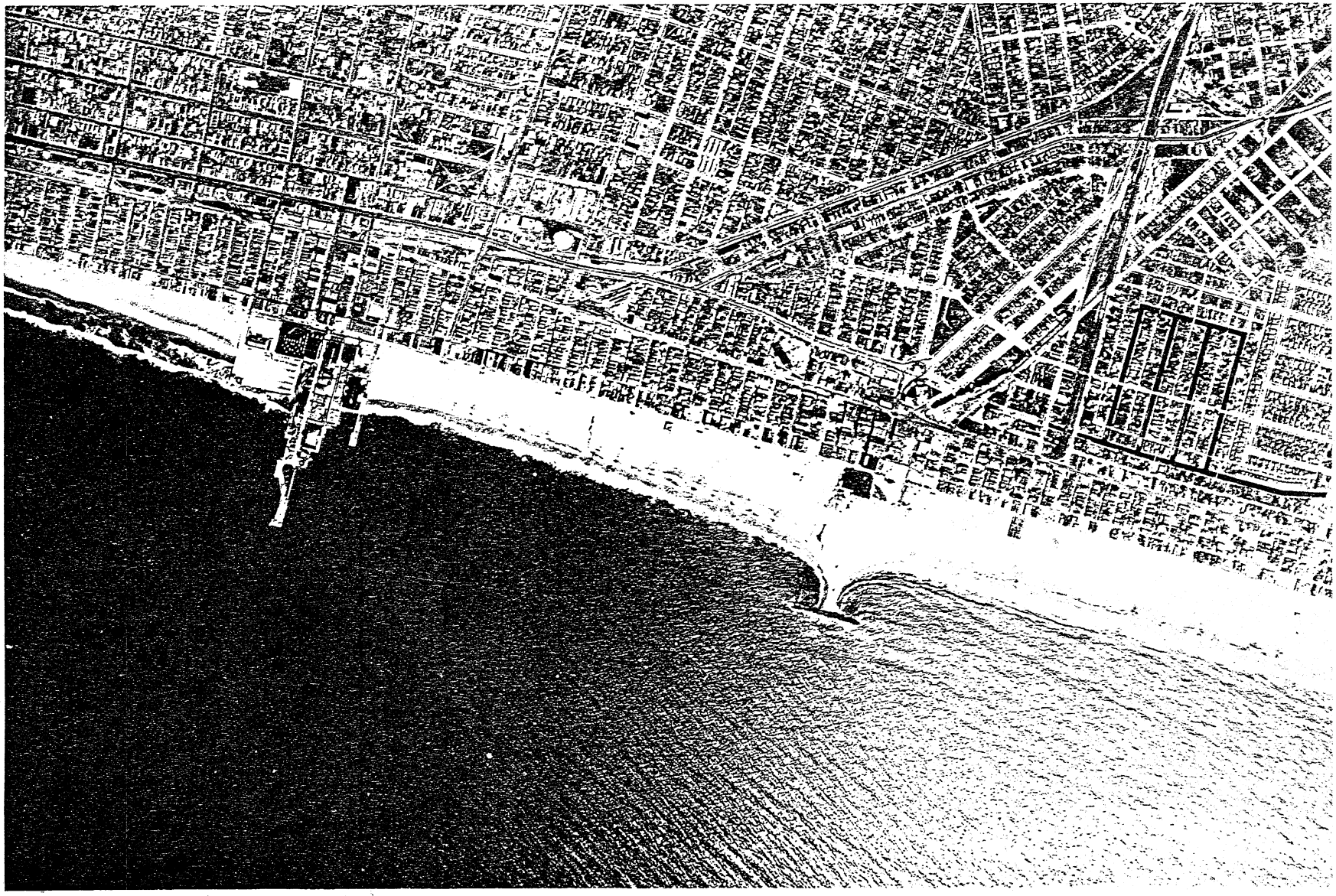
Siting Offshore Breakwaters Seaward of Seawalls for Protection



Channel Islands Harbor – Port Hueneme, California – Sept. 1965



Siting of Offshore Breakwaters for Sheltering Harbor Entrance



Venice, California (before 1948)

Breakwater Acting as Complete Littoral Barrier Causing a Tombolo

APPENDIX C

Gradation report

SINCE 1972

TWIN PORTS TESTING INC.

1301 NORTH THIRD STREET • SUPERIOR, WISCONSIN 54880
(715) 392-7114 • FAX (715) 392-7163

728 GARFIELD AVENUE • DULUTH, MINNESOTA 55802
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Number of pages to be transmitted: 8
Date: 9/11/95

Please Deliver the Following Pages To:

Name: BRUCE RASMUSSEN.
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Telecopier Number: (612) 874-9793

TPT project number: 556-95E.
TPT faxsimile number: (218) 722-3295
TPT phone number: (218) 722 1911

This Telecopy is being sent by: MAHESH ALBUQUERQUE.

Remarks:

Bruce,

As per instructions from Mr. Bob Holmgren from R. W. Docks & Slips we are sending you the analytical results for four sediment samples collected at the Port Superior Marina in Bayfield, Wisconsin. Please call me at (218) 722-1911 if you need any further information.

Sincerely,

Mahesh Albuquerque.

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(906) 226-6653 • FAX (906) 226-3699

Project R & W Docks and Slips
Client TPT 556-95E
Description (SP) Poorly Graded Sand with Silt
Specification Informational FA Only
Source SS-1
Copies To

TPT # 1318-95MG
Lab Sample No. 319
Sampled By TPT/MA
Date Sampled 08/31/95
Date Tested 09/11/95

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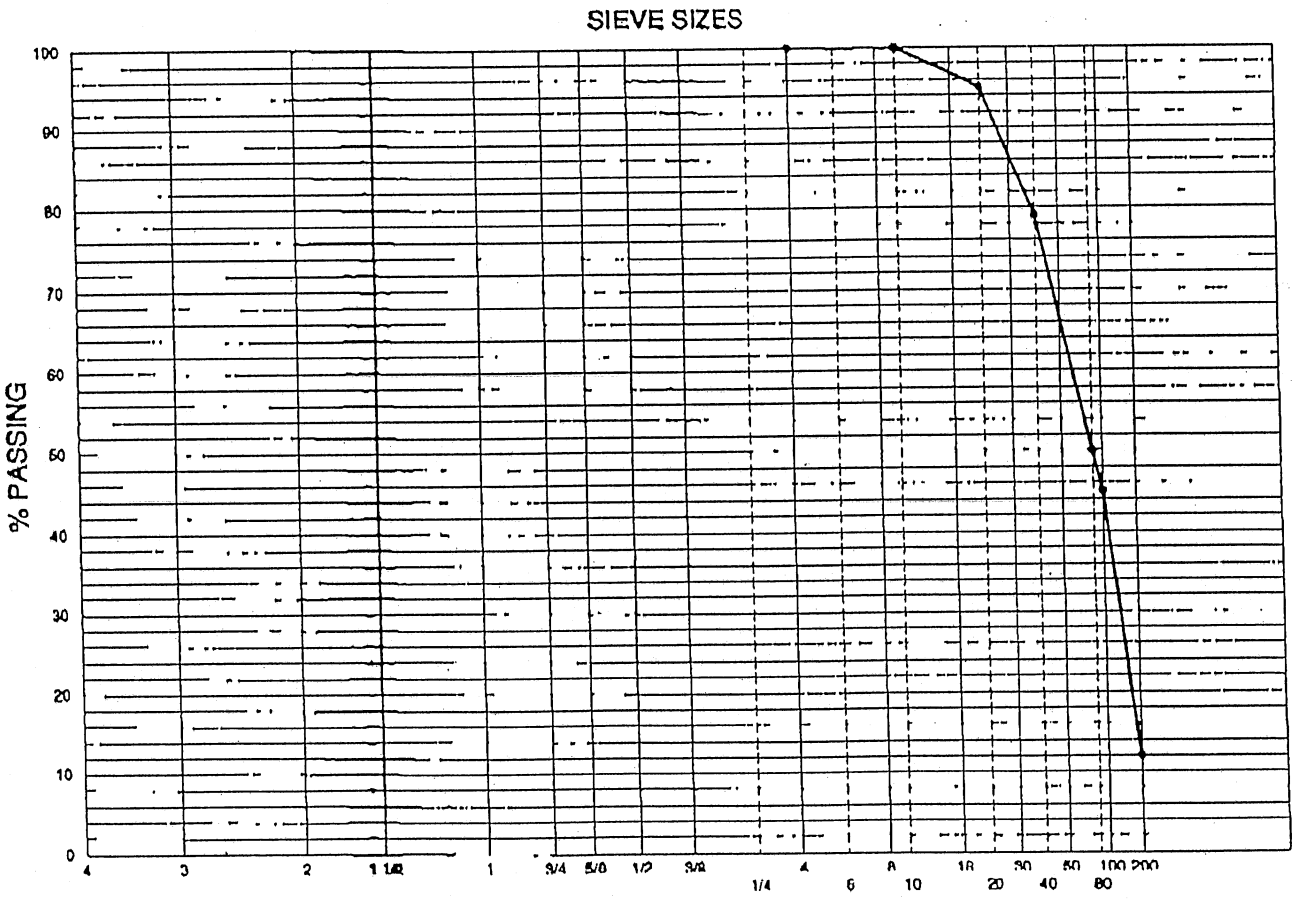

Remarks A lot of organic material in the sample.

GRADATION REPORT

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(906) 226-6653 • FAX (906) 226-3699

Project R & W Docks and Slips
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Specification Informational FA Only
Source SS-2
Copies To

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Lab Sample No. 320
Sampled By TPT/MA
Date Sampled 08/31/95
Date Tested 09/11/95

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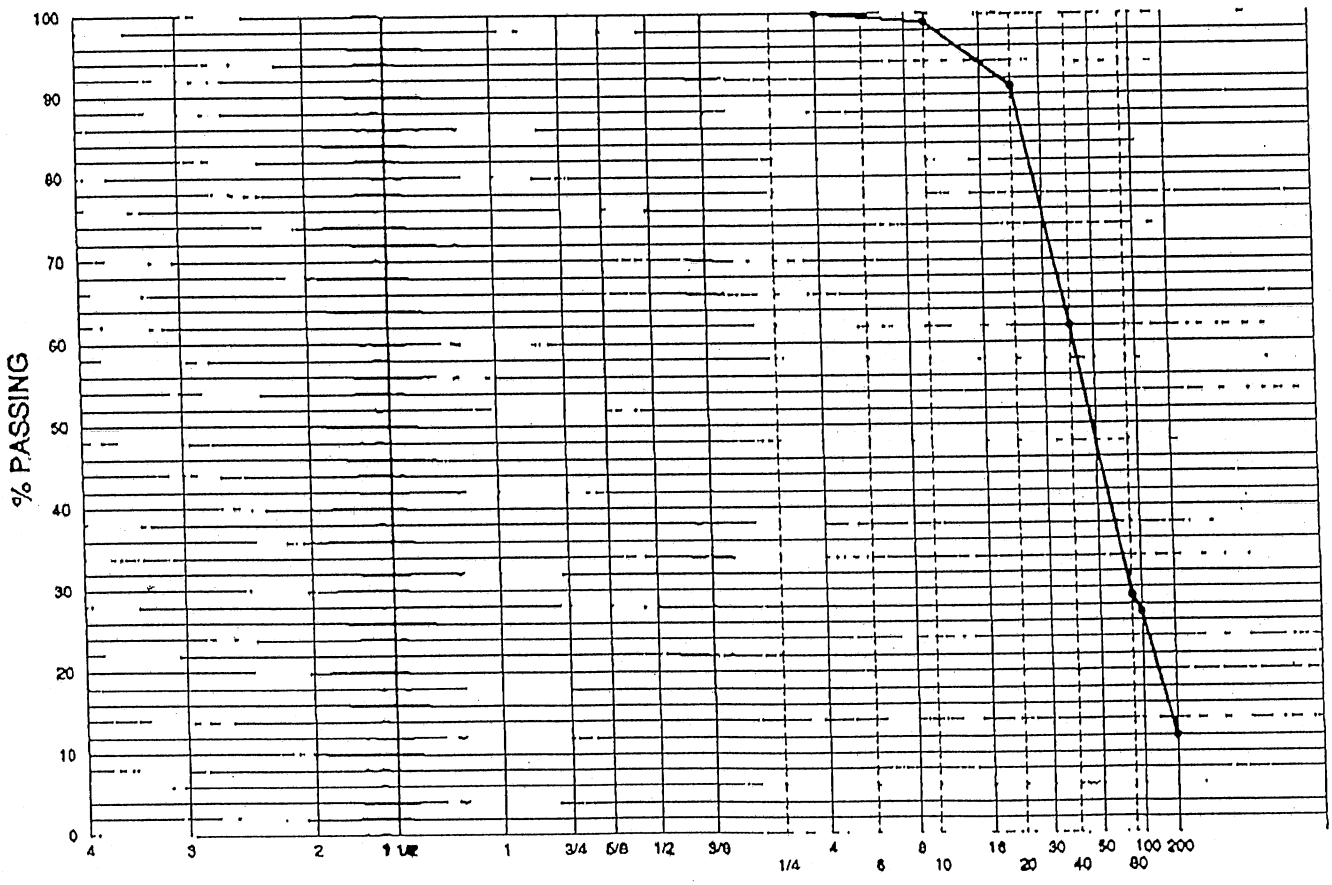

Remarks Organic material present.

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(906) 226-6653 • FAX (906) 226-3699

Project R & W Docks and Slips
Client TPT 556-95E
Description (SM) Silty Sand
Specification Informational FA Only
Source SS-3
Copies To

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Lab Sample No. 321
Sampled By TPT/MA
Date Sampled 08/31/95
Date Tested 09/11/95

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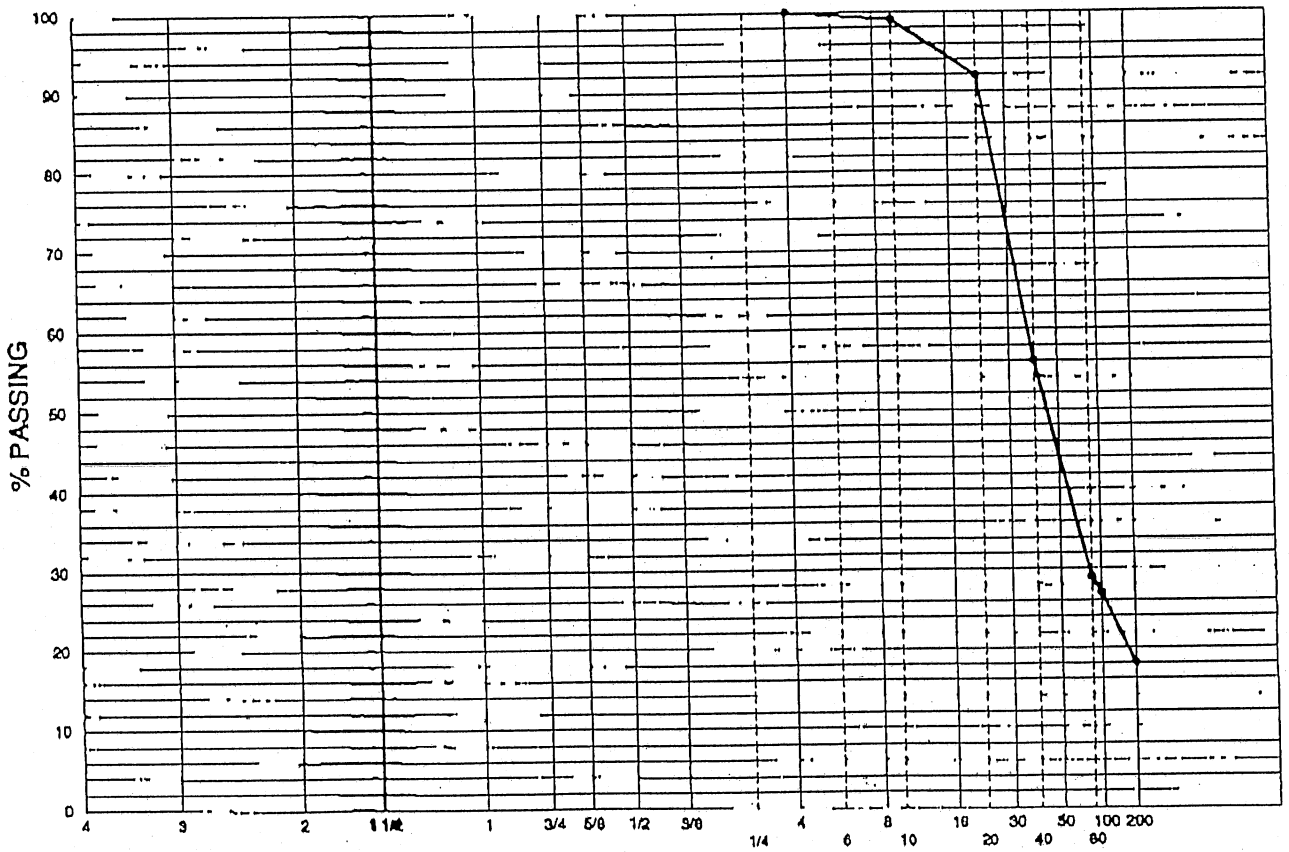
SIEVE SIZES



Remarks Organic material present.