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WISCONSIN
COASTAL
MANAGEMENT
PROGRAM

CROSS-CHANNEL DEEP HOLE DESIGN INVESTIGATION

NORTHWEST REGIONAL PLANNING COMMISSION

SEPTEMBER 1991

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SUPERIOR HARBOR
CROSS CHANNEL DEEP HOLE

Design Investigation

SEPTEMBER, 1991

THE NORTHWEST REGIONAL PLANNING COMMISSION

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TABLE OF CONTENTS

I. INTRODUCTION

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A. HISTORICAL PERSPECTIVE

The original harbor construction project for Superior, Wisconsin was authorized in 1867 and for Duluth, Minnesota in 1871. The ports were combined in 1896 and have been expanded and modified by more than ten River and Harbor Acts. Maintenance of the Federal Project areas have been the responsibility of the U.S. Army Corps of Engineers (USCOE) while private portions of the harbor are maintained by their owners. Maintenance of the harbor is generally confined to three types of work: 1. Maintenance and expansion of the navigation channels, including dredging and the disposal of dredged materials; 2. Maintenance of aids to navigation; and, 3. Maintenance and expansion of shoreland infrastructure related to recreation and commodity movement.

During the 1970's the State of Wisconsin expressed serious concerns about contamination of dredged materials and the deposition of pollutants in the Great Lakes. The State recognized that small amounts of pollutant materials could have harmful effects on the human health. In 1975 the State, in keeping with its commitment to a high quality environment, requested that all open water dumping of dredged material in the adjacent waters of the state be stopped. Based on this request and others, in-water disposal was stopped in Wisconsin Great Lakes waters.

In the early 1980's the Governor requested that the Wisconsin Coastal Management Council define dredging needs and problems of Great Lakes harbors and to report on the impact of federal dredging policies upon the economic status of those harbors.

Since the Wisconsin Department of Natural Resources prohibition of in-water disposal, the Erie Pier Contained Disposal Facility has been receiving approximately

150,000 cubic yards of dredged materials per year from public maintenance dredge activities in the combined harbor. Since the site has only two or three years of capacity remaining, new sites must be identified that may meet the requirements of current and proposed state and federal dredge and disposal regulations. In addition, the disposal needs of private slip owners must also be recognized.

While many valid research reports have already been completed on the combined harbor during the late 1970's and early 1980's, no recent attempt has been made to fill the gaps in the existing information. Nor were those existing reports responsive to the current or proposed level of permit regulations in Wisconsin.

B. PREVIOUS WORK

In 1988 the NWRPC proposed a harbor dredged materials disposal study project to the Wisconsin Coastal Management Program to identify information gaps on three potential sites for disposal of dredged materials. The project was funded in 1988 and completed in late 1989.

One finding of that report was that consideration be given to Cross-Channel Deep Hole and Interstate Island as a demonstration or pilot project. Its potential for multiple habitat creation (wildlife refuge, wetland creation, fish habitat) as well as a dredged material disposal site is a unique opportunity.

C. CURRENT PROJECT STATEMENT

The current Deep Hole design investigation work was devised to feasibility of island creation as a means to safely dispose of dredged material and create new habitat.

1. <u>Problems</u>:

Construction of harbor facilities has reduced available fish habitat in the Duluth/Superior Harbor. Over the years, construction of man-made facilities has continually eroded the availability of fish habitat as well as wetlands and other natural habitat. This is typical of all estuary harbors.

Erie Pier, the only contained disposal facility (CDF) in the Duluth/Superior Harbor, has 1-2 years of remaining capacity. Additional capacity will be needed by 1992 or 1993 if a maintenance dredging program is to continue. Approximately 150,000 yards of dredged material is disposed of annually by the Corps of Engineers maintenance dredging program. Further, not all the material is sufficiently polluted to require CDF disposal by EPA/Corps standards, yet there are no other disposal facilities available. There is a need for additional disposal methods.

Further, there should be a variety of disposal alternatives; such as beach nourishment, upland, in-water contained, as well as CDF disposal.

This study addresses both of these problems simultaneously by preparing alternative preliminary designs for the creation of fish and wildlife habitat, and wetlands through the utilization of dredged materials.

Further, construction activities in the Harbor, such as replacement of highway ramps and bridge decks, produce waste materials. This demolition material has potential as shore protection rip-rap and fish habitat material. Recrushed concrete could provide material for fish spawning beds and concrete aggregate.

While dredged material may be considered a waste material, it can also be considered a material of construction. Once viewed as a material of construction, there is an opportunity to shape and form materials into desirable earth forms--whether that be filling of mainland areas, creation of islands, or filling of abandoned mined holes or abandoned slips and channels.

The opportunities to use other waste materials for construction was explored. The nearby I-535-Blatnik Bridge is scheduled for bridge deck replacement. The old concrete bridge deck has potential to be recycled as rip-rap for fish habitat and shore protection. Recrushed concrete has potential for concrete aggregate and fish spawning beds. An opportunity exists at Interstate Island and Cross-Channel Deep Hole located in the Duluth/Superior Harbor to examine the potential of waste materials as construction materials.

The Cross-Channel Deep Hole has been identified as a potential dredged material disposal site in a number of reports. Interstate Island is a man-made island created out of dredged spoils. The island currently shows promise as a tern habitat.

Design investigations for multiple enhancement of habitat in conjunction with dredged material disposal operations. The design investigation is driven by natural resource considerations rather than dredging considerations.

II. EXISTING CONDITIONS

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A. GEOGRAPHIC SETTING

Duluth-Superior Harbor is located within the two cities and occupies roughly 32 square miles with over 100 miles of waterfront. The harbor is protected by a natural sand and gravel spit six miles in length that was formed by the deposits of the St. Louis and Nemadji Rivers as they outlet to Lake Superior. This protecting spit is penetrated by the Duluth Ship Canal and Superior Entry. The bar is known as Minnesota Point north of the Superior Entry and Wisconsin Point south of the entry. Two inner spits, Rice's and Connor's Points, divide the twin ports into inner and outer harbors. The outer harbor consists of Superior and Allouez Bays while the inner harbor is St. Louis Bay and upstream on the St. Louis River.

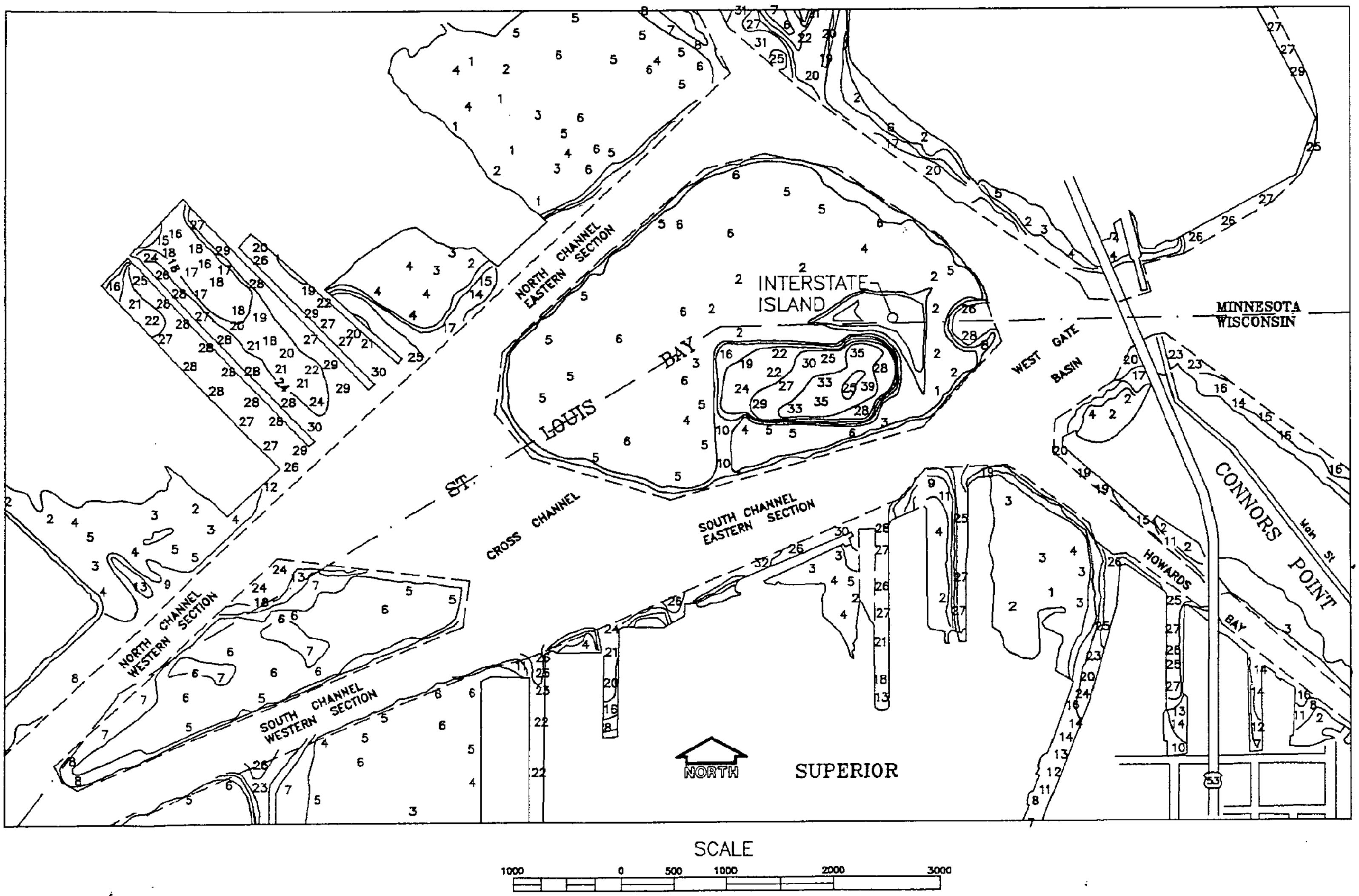
The harbor is located in the estuary of the St. Louis River which originally covered an estimated 11,500 acres. Development of the harbor has resulted in dredging of approximately 4,000 acres and filling of an additional 3300 acres.

B. TRANSPORTATION SYSTEMS

Water Transportation

The water transportation system is contained wholly within the harbor boundaries. The system consists of channels, aids to navigation, and navigational structures. The primary water channels are owned and maintained by the public to be utilized for any appropriate transportation use in the same manner as the public highways. They are, however, perceived by the public as necessary extensions of the water commerce industry. This is reinforced by the almost total lack of water borne passenger service. Nearly all trips on the system consist of an origin or destination outside the harbor for the movement of commercial goods.

CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION



STUDY AREA

PRELIMINARY STUDY AREA INCLUDING ADJACENT SHORE LINES FOR EVALUATION OF PREDOMINANT WIND AND WAVE PATTERNS AND PROXIMITY OF PREDATOR EASE OF ACCESS.

STUDY AREA INCLUDES THE MUD FLAT SURROUNDING INTERSTATE ISLAND.

WATER DEPTHS TAKEN FROM NAVIGATIONAL CHART #14975.

Following is a brief description of the major public and private channels:

Superior Entry - The Superior entrance to the harbor between Wisconsin and Minnesota Points is protected by two rubble mound breakwaters which form a stilling basin.

Allouez Bay Channel - The channel aids in accessing two docks.

Superior Harbor Basin - Provides an anchorage and maneuvering area. It serves the Burlington Northern ore dock areas and the mouth of the Nemadji River.

Superior Front Channel - Serves Superior's eastern waterfront.

Duluth Ship Canal - The Duluth entrance to the harbor dug in 1871; crossed by the Aerial Lift Bridge.

Duluth Harbor Basin - Provides an anchorage and maneuvering area. Serves Duluth's Railroad Street and eastern Rice's Point.

East Gate & West Gate Basins - These lie on opposite sides of the gateway between the outer and inner harbors. The John Blatnik (High) Bridge arcs overhead.

St. Louis Bay North Channel - Serves the Duluth waterfront from Rice's Point to Erie Pier.

Twenty-First Avenue West Channel - Serves the 21st Ave. West slip, but is not currently maintained to project depth.

St. Louis Bay South Channel - Serves the Superior waterfront.

Cross Channel - Facilitates shipments from the DM & IR docks and provides maneuvering room.

Howards Bay - Serves both sides of Howards Bay and the Fraser Shipyards.

Upper Channel - Provides a connecting link with the North and South Channels and the Minnesota Channel.

Minnesota Channel - Provides access to docks in West Duluth.

St. Louis River Natural Channel - Non-maintained portion of the river upstream to Fond du Lac.

Except for the St. Louis River channel, these channels and structures are publicly maintained. Branching off these primary channels are many privately maintained channels serving harbor users.

Most of the harbor is maintained at a 27 foot project depth. Current proposed modifications of the Cross Channel, Upper Channel and Minnesota Channel to greater depth and width will enable vessels to carry larger cargos at enhanced maneuvering speeds; both of which represent savings in vessel operating costs and enhanced economic benefit to the region.

Ground Transportation

The ground transportation network serving the harbor is a diverse system of railroads, highways and airports influenced by the configuration of the waterfront.

Major railroads serve the area to handle the bulk of traffic to the region. Major cargos are: grain, coal, iron ore, general freight and bulk commodities. Within the harbor area, access to rail service is generally good with most existing or potential industrial sites having ready access. The area also has railroad classification yards to facilitate cargo routing. Street and highway networks are generally good although some bottlenecks occur during the summer tourism season and the grain harvesting/shipping season which are usually local in nature and effect.

C. TOPOGRAPHY AND GEOLOGY

1. General

The appearance of the present landscape is due largely to the effects of Wisconsin glaciation and to postglacial events during which several ice sheets advanced and retreated over the area, filling valleys, gouging out lakes and forming ridges and hills. The present shoreline of Lake Superior was shaped largely during the Great Ice Age.

The north shore of Lake Superior is underlain by Keweenawan lava flows that form the Laurentian Upland, rising 500 to 1,000 feet above the lake. These flows occupy an area along the shore that extends inland for 10-20 miles. This area is bordered on the north by the Duluth Gabbro which extends from Duluth to Grand Marais.

A number of short streams drain the Superior upland; most of which cascade in falls and rapids almost directly to the lake, resulting in a scarcity of good harbors along the north shore. This is due to a north-to-south tilting of the Lake Superior basin, which is also responsible for creating "natural" harbors along the south shore of the lake as a result of the drowning of river mouths.

Duluth-Superior Harbor occupies the drowned river mouth of the St. Louis River.

The City of Duluth stands at the head of Lake Superior, where a series of rock formations converge. An escarpment rises sharply above the harbor on the Duluth side and is composed of the Duluth Gabbro.

In contrast to the rocky bluffs above Duluth, which are typical of most of the north shore, low plains of lacustrine red clay dominates the shoreline around the City of Superior and extend several miles inland. These contain the watersheds of the Nemadji and Pokegama Rivers, and a number of smaller streams tributary to the harbor. Bedrock formations in this area are buried beneath a heavy mantle of glacial lake sediments.

2. St. Louis River Sub-Basin

The St. Louis River has a drainage area of 3,647 square miles. The river is used extensively for hydroelectric power generation, iron ore processing, and pulp and paper manufacturing. Average annual runoff for the area is about 9 inches with a surface water storage capacity of approximately 340,000 acre-feet.

The sub-basin can be divided in two distinct portions. Upstream from Cloquet, the river water is generally of high quality. Flow variations are seasonal and vary greatly. Low flow along the upper segments may pose problems because of the many municipalities and extensive industrial use. Below Cloquet, the river flows through the scenic gorge of Jay Cooke Park before entering St. Louis Bay. Prior to the on-line operation of the Western Lake Superior Sanitary District the lower portion of the river was in poor condition due to the stream's ability to handle waste discharges. However, recently the river has steadily been improving in water quality.

While the river flows through erodible red clay soils, much of the sediment generated is trapped by the numerous hydroelectric facilities present. Below Fond du Lac however the riverbanks are subject to catastrophic erosion during periods of unstable flow.

Streams of the upland clay soil areas in the sub-basin have sediment yields estimated by the U.S.G.S as high as 500 tons per square mile per year. In the past however, only suspended sediment has been monitored. Transport studies to identify suspended and bed load contributions generally have not been undertaken. Usage of the USGS estimated sediment yield is inappropriate for estimation of dredging quantities since it does not take into account the high rate of catastrophic stream bank erosion common to the region.

For the purposes of this report, a more reliable method of estimating future dredge quantities is to examine historical dredging activities and make assumptions about the reliability of the data. It is recognized that this approach does not address sediment entering the harbor area and being deposited outside the arbitrary dredge project limits.

3. Nemadji River Sub-basin

The Nemadji River sub-basin comprises 460 square miles in Minnesota and Wisconsin. Clayey soils make up 40% of the area. Land use consists mainly of forest lands (90%) with the balance in agriculture and urban use.

The sub-basin is essentially a level plain into which the rivers and streams have become deeply incised and meandered. The depth of the incision and meandering has caused bank instability along most of the length of the river's main stem and primary tributaries located in the clay zone.

In 1975, a streambank erosion inventory was conducted on the main stem and the two primary branches of the Nemadji which identified 154 major sites of channel erosion or massive bank losses over the 60 mile channel length not including the many smaller tributaries.

A major man-made source of sediment in the clay zone is roadside erosion which in most cases is caused by inappropriate maintenance and construction activities. In 1975, an inventory of all sub-basin roadside erosion sites was conducted. The result indicated a need for treatment of nearly thirty acres of roadside ditches and berms and the need for nearly twenty flow and sediment control structures.

As in the case of the St. Louis sub-basin, no major transport studies have been conducted to determine the actual contributions of the Nemadji system to the Duluth-Superior Harbor.

Again as in the case of the St. Louis sub-basin, historical dredging quantities will be used for the estimation of future dredging needs.

D. CLIMATE

The climate in the harbor area is greatly influenced by a succession of high and low pressure systems that continually cross from west to east. Lake Superior, the largest and coldest of the Great Lakes, also influences the weather especially in the spring and summer. Often the effects of the winds and the lake cause sharp temperature differences even within several miles of the lake.

Winds are primarily easterly in the summer and generally from the northwest in the other months. The average annual temperature is 39 F with January the coldest month and July the warmest month. Temperatures along the lakeshore may vary greatly during any one day. Over the period of record, temperatures have ranged from a low of -41 F to a high of 106 F.

E. FLORA AND FAUNA

This section is summarized from a number of reports and environmental impact statements prepared for a variety of projects within the harbor area.

1. Habitat

Fifteen major habitat types have been identified in or adjacent to the harbor. They are described briefly as follows:

Open Water

Mudflats. Unvegetated or sparsely vegetated areas characterized by silty, muddy substrates. The size of the area is dependant on fluctuations of water levels.

Emergent Aquatic. Nonpersistent hydrophytic vegetation that grows above the water surface. Plants fall to the surface of the substrate at the end of the growing season.

Cattail-Sedge Marsh. A wetland dominated by the two plants which remain standing until the beginning of the next growing season.

Woody Marsh. A wetland dominated by woody vegetation types: broad-leaved deciduous, needle-leaved deciduous, broad leaved evergreen, and needle-leaved evergreen species.

Sandy Beach. Unvegetated or slightly vegetated areas consisting of sloping land forms generated by waves and current which are composed predominately of unconsolidated sand, gravel, or cobbles usually continuous with the shore.

Tree Sapling. Consisting of young trees, usually birch or aspen.

Grass Meadow. Land covered with grasses and other narrow leaved plants.

Weedy Field. Land predominately covered with broad-leaved herbaceous plants.

Shrub. Land covered with low, woody vegetation generally between 1 and 3 meters high.

Hardwood-Deciduous Forest. Land covered by at least 10% tree crown coverage and dominated by aspen, birch, maple and other broad-leaved deciduous trees.

Mixed Deciduous-Coniferous Forest. Land covered by at least 10% tree crown coverage on which both coniferous and deciduous trees occur and neither predominates.

Coniferous Forest. Land covered by at least 10% tree crown coverage and dominantly forested with needle leaf species.

Residential. Land used for dwelling units.

Industrial. Land that has been developed for commercial or industrial uses.

Of these habitat types in the area, those that are more important as fish and wildlife habitat are the emergent aquatic vegetation, cattail-sedge marshes, grassy-weedy areas, upland forest, sand areas and open water areas.

Open water areas, which comprise the largest habitat type within the harbor, consist primarily of dredged shipping channels greater than 20 feet deep and shallow water areas from 0-6 feet deep. The majority of the latter areas do not have established beds of aquatic vegetation because of wave action or lack of suitable substrate.

In the reports used for this section no endangered or threatened taxa were noted.

2. Birds

The location of the harbor makes it an excellent location for nesting and a stopping place for a large bird population. This is because Lake Superior is the end of a continuous pathway from the Atlantic Ocean for the movement of ocean species; migrating birds from the north and south avoid crossing large bodies of water and are directed around Lake Superior past the harbor; and, the presence of many unique habitats. Over 236 species have been identified in the area. Excluding colonial bird nesting areas, the most heavily used areas include the Allouez Bay-Wisconsin Point area,

4. Reptiles and Amphibians

Amphibians and reptiles are not abundant in the region with only about a dozen species noted.

5. Fish

Thirty-nine species of fish inhabit the nearshore or harbor areas of Lake Superior; among them are herring, whitefish and cisco, trout, smelt, suckers, perch, sculpin, walleye, northern pike, bass and bullhead. The game species present in significant numbers are northern pike, walleyes and yellow perch. Major forage species include bullheads, spottail shiners, emerald shiners, juvenile perch, white and longnose suckers and rainbow smelt. Water temperatures and oxygen concentrations apparently preclude the use of the harbor by salmon or trout although they have been noted as spawning in the Nemadji River system.

Gill net catches have reported showing a tendency for all food species, except burbot, to inhabit shallow areas. This tendency to concentrate in shallow water is of special significance to the problem of dredged material disposal. Disposal of sediments has created artificially shallow areas which are favorable habitat with respect to food, light conditions and temperature. Heavy metals in the sediments may subsequently promote the direct uptake of potentially toxic compounds by fish attracted to the area, as well as bottom feeding organisms which serve as fish food.

Both yellow perch and northern pike are well distributed throughout the shallow areas of the harbor and both overwinter in the harbor area. The perch utilizes living beds of emergent vegetation for spawning habitat. Northern pike typically spawn over dead grass and sedges flooded by spring high water, however with a lack of this habitat due to water levels, they appear to utilize submerged aquatic vegetation in Allouez Bay, along Grassy Point and other emergent wetlands.

Walleye appear to spend late summer, fall and winter off the Wisconsin shore of Lake Superior. Studies indicate that walleyes begin entering the harbor in late February on their spawning run up the St. Louis River to the first rapids. After spawning they may either return immediately to Lake Superior or spend time feeding on the abundance of forage fishes in Superior and Allouez Bays. By mid-July, the majority of adults have returned to Lake Superior.

Walleye fry drift down to the harbor area shortly after hatching and spend most of the summer within the harbor feeding first on zooplankton before switching to perch fry as the latter become available. Planktonic algae and zooplankton production is limited to the depth of the photic zone, normally about four to seven feet in the system. Consequently, good perch and walleye nursery habitat is comprised of an abundance of open, shallow water areas protected from strong wave action. Such areas are scattered throughout the lower harbor exclusive of slips and navigation channels.

Other Lake Superior fish species entering the harbor for spawning include rainbow smelt, emerald and spottail shiners, longnose suckers, white suckers, silver redhorse and burbot.

There are no citations of Federally endangered or threatened fish species in the harbor. Two recently introduced species (white perch and the river ruffe) are of concern to area fisheries specialists because of unknown populations and impacts.

F. LAND USE

The present day land use pattern in the harbor is a result of a 100 year process of change which continues to be dynamic; continually adjusting to local needs and the national economy. The following table summarizes the composition of current uses found in the harbor. A 1989 Harbor Land Use map is found in the pocket page.

Naturally water comprises the vast bulk of the harbor area although only a portion of the area is used for transportation. Of the land uses open space is the largest category consisting of parks and municipal forests.

Shipping is the most significant land use. The elevators, ore and coal docks, and general cargo facilities cover sizeable portions of the waterfront.

III. DESIGN REPORT

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A. HABITAT CREATION

1. Criteria for the Creation of Aquatic Wetlands

Interviews and meetings were held with Wisconsin Department of Natural Resources personnel and Minnesota Department of Natural Resources personnel to establish criteria for creation of aquatic wetlands, fish habitat and waterbird habitat. Personnel involved were:

Fred Strand, Wildlife Manager, Wisconsin DNR;
Dennis Pratt, Fish Biologist, Wisconsin DNR;
Richard Schaefer, Wildlife Manager, Minnesota DNR;
and John Chell, Regional Administrator, Minnesota DNR.

It was determined from the interviews and meetings that the best approach to wetland creation would be to create or re-establish the types of wetlands lost in the middle harbor area. Those were determined to be deep and shallow marshes, containing submergent as well as emergent vegetation. Those areas in the middle harbor--particularly along north channel and south channel--have had a significant loss of important wetlands over the past 120 years to establishment of lines, bulkheads, docks and other marine terminal and transfer facilities. The most desirable action is to replace that type of habitat lost with a similar habitat. It is felt that in the Duluth/Superior harbor, little, if any, wetland vegetation grows below a depth of 6 feet. Therefore it is felt desirable to have depths no greater than 6 feet and preferably no greater than 3 feet.

It was determined that wetland vegetation does not re-establish itself where there are moderate to heavy wave energy forces.

Research of the literature did not identify information indicating at what particular wave heights wetland vegetation could survive. However, those interviewed seemed to feel that wave heights should be maintained below the one and one-half feet. Therefore, the following criteria was developed: areas of wetland creation should be in no greater than six feet of water depth; and preferably no greater than three feet of water depth. Second, wave heights should be less than one and one-half foot, preferrably less than one foot.

Further, interview with Don Reed, wetland biologist, confirmed the opinion of the wildlife and fish management personnel of the two DNRs. Mr. Reed indicated that slopes of less than 8 to 1 or less are desirable for creation of wetland vegetation. Further that flat slopes allow a variety of vegetation. Further Mr. Reed recommended planting of wetland vegetation in order to accelerate the growth process. He recommended native species existing in the harbor be used and that at least two separate species be identified for each water depth or each specific location. The criteria for the creation of aquatic wetlands was then expanded to include the following criteria. That slopes, if possible, would be 8 horizontal to 1 vertical or flatter. That plantings be utilized to accelerate the establishment of wetland vegetation. That two or more species known to be locally adapted should be planted.

2. Criteria for the Creation of Waterfowl Habitat and Migratory Waterfowl

Waterbird Habitat

A number of species were discussed, including the piping plover. Minnesota DNR felt it would be desirable to try to create an island specifically to re-establish the piping plover in the Duluth/Superior Harbor. They further thought it would be desirable to create tern habitat. Experience on the

Interstate Island refuge indicated that the terns and plovers when they did occupy the island, preferred a sparsely vegetated site, windy with relatively flat slopes. In order not to be over run with ringed-bill seagulls, it was felt desirable to have a relatively small separate island. Criteria for plover islands was to have a small island, perhaps two acres in size, somewhat separate from other islands with open faces toward the wind (northwest or east), and sparsely vegetated. The criteria for desirable waterfowl habitat, particularly migratory waterfowl, is to have some open water, semi-protected and protected, adjacent to wetlands for foraging.

3. Criteria for Fish Habitat

It was felt desirable to create forage areas for juvenile fish. The immediate study area appeared to be too warm for spawning of game fish, although it was felt that riprap may encourage rock bass. Wisconsin DNR felt that the project should not to try to be specie specific in the creation of fish habitat but rather to build habitat suitable for juveniles of all species.

Dennis Pratt, fish biologist, recommended that creation of aquatic wetlands was the most desirable way of improving fish habitat. Therefore, it is presumed that the criteria for creation of aquatic wetlands are also the criteria for providing juvenile fish habitat. The interviewed parties indicated that we should not limit our investigations to only deep hole and interstate island. They thought the entire submerged flat area contained between south channel, north channel, cross channel, and west gate area provided a great opportunity to expand the potential. It was further recommended that this study not be State specific. Based on the recommendation of the natural resource professionals, NWRPC expanded the study area to cover the entire submerged flat area. It is essentially quadrupled the study area.

B. Application of Habitat Criteria to Study Site

A review of the depths of the study area (see base map) indicate that there were no depths greater than six feet. More specifically, six feet below datum of 600 (IGLD 1955). During high water periods, there may be some depths over six feet. There are extensive areas with depths ranging from two to five feet. Therefore, the study area depths were suitable to meet the depth criteria. The wave climate in the location does not lend itself to wetland creation. The area was open to wave attack from numerous directions. The report in Appendix B indicates for study purposes that wave heights of 2.5 feet from the northeast and 2.0 feet from southwest could easily attack any potential wetland vegetation in the entire area. Therefore, protective breakwaters are needed to be planned to reduce wave height. Trial plan 1 shows the application of a series of islands called breakwater islands in this study. The purpose was to primarily to break the flat area and create a quiescent area in the center of the flat area. Wave studies indicated that by closing the opening between islands to approximately a maximum of 100 feet that attack waves could be controlled and reduced within the flat area.

In order to create a variety of depths, it seemed logical that the protected side of the artificial islands have the desirable slope to support emergent wetland vegetation. The slope of 10 to 1 was selected in order to insure that at least 8 to 1 would be reached--presuming there may be some irregularities from construction activities.

Breakwater islands, however, did not meet the criteria for the plover or tern habitat. Therefore, an addition type of island--a small circular island--named a plover island for the study was developed. Trial plan 2 shows the prototype of plover island, as well as a crescent island. The crescent island was developed using the experience on the Mississippi River, where this shape has been successful. It also permits the curved tips of the crescent to provide better protection to the desirable 10 to 1 slopes on the protected side of the island.

C. Engineering Criteria

Soil Mechanics

A number of engineering criteria were evaluated for this design investigation. In the general field of soil mechanics, slope stability was investigated. Slope stability with the safety factor of 1.5 was set as a criteria for this investigation. Of great concern was the additional load placed by the potential islands on the submerged flat. This additional island surcharge load will increase the shear stress on the channel sides.

Wind & Waves

For the purposes of this study, a 20-year recurrence interval was determined to be adequate for wind and wave analysis. From the study of U.S. Weather Station in Duluth, U.S. Coast Guard Station at Minnesota Point, the wind velocity and direction were determined. 20-year wind was determined to be 42 m.p.h. For comparison, a 5-year wind velocity is 35 m.p.h. and a 40-year wind velocity is 45 m.p.h.

The design wind velocities were applied in all directions. Wind driven wave forecasts in 10 degree increments were done for 5-year, 20-year, and 40-year reoccurrence intervals. The two highest design waves were from asmith 90^{o} if (east) and asmith 220^{o} (southwest). Wave heights were 2.5 feet and 2.6 feet, respectively, for the 40-year currents, 2.4 feet and 2.5 feet, respectively, for the 20-year currents and 1.9 foot and 2.0 feet for the 5-year currents interval. For the preliminary design of shore protection a design wave of 2.5 feet was selected.

Appendix B further details wind, wave, ice, structural and slope stability design criteria.

D. Application of Engineering Criteria to Study Site.

Soil Mechanics

One of the findings of the engineering study was that the submerged flat soil tended to be weak and poorly consolidated. Information is indicated in Appendix E, Boring Logs. The slope stability analysis indicated that the slope from the toe of the channel to the island location should be approximately at a rate of 8 horizontal to 1 vertical (8:1). This necessitated relocating the islands to a some what more central location on the flat area, in order to maintain a safety factor of 1.5 in slope stability.

Wind and Wave Forces

Wave analysis indicated that with openings of 250 feet or more between islands 2.5 foot waves could come through with little or no attenuation of wave height. The extension of Interstate Island, shown as item G in the Final Plan, should be lined with riprap in order to act as a energy dissipation area for wind driven waves from the east.

The wave analysis shows a 1.9 foot wave will build within the submerged flat area during design wind conditions; therefore, it was necessary to divide the flat into sub areas in order to reduce wave heights to the established design criteria.

The wave facing side of the islands utilize a two-layer riprap armor system. The riprap amour system on a 2 horizontal to 1 vertical (2:1) slope. Two to one is based on engineering judging and experience in the Lake Superior area. It provides a safe slope which is relatively efficient in quantities of construction materials. Top elevation of the riprap was set at 606.0 based on a calculated runup elevation of 605.4. This is also consistent with the armor utilized on Erie Pier CDF and other structures subject to similar wave attacks.

In addition to wind driven waves, there is potential for wake waves and displacement waves caused by commercial vessels. The COE analysis of Eric Pier indicated a 2.5 foot design wake wave. Since this is the same size as the wind driven waves, no separate analysis was made for wake waves.

Demolition material from the Blatnik Bridge. The use of demolition material from the Blatnik Bridge deck replacement project was evaluated. That material was considered for potential riprap armor. Contacts were made with William Kline, P.E., and Robert McFarlin, P.E. of the consulting engineering firm of Parsons, Brinkerhoff, Quaid and Douglas Company, Inc. of Minneapolis, Minnesota, Minnesota DOT's consulting engineer for the Blatnik bridge deck replacement. Information from that firm indicated that because of the relatively thin deck (6") and heavy re-enforcement in the deck that the demolition particle sizes would be too light to meet the weight requirements for the armor layer or the under layer. Use of bridge demolition material was eliminated for further consideration in this design investigation.

Surface Slope

A top slope on the islands is shown as desirable at 2% (50:1). A 2% slope will provide drainage; however, eggs of waterbirds will not roll on a 2% sand slope.

Island Volume

Island size were selected to be approximately 50-60,000 c.y. volume. This size is preferred because it would allow the completion of an entire island of one construction season. The annual maintenance dredging in the Duluth/Superior Harbor typically ranges from 120,000 c.y. to 150,000 c.y. per year. Presuming that approximately one-half of the dredged material would be suitable for island construction, then 60,000 c.y. makes a reasonable size for construction in one year. Obviously, there is a multitude of other island size alternatives, as well as potential of constructing an island over two or more construction seasons.

Appendixes B and C further provide further insight into the engineering evaluation.

The final drawing incorporate these engineering criteria.

E. Estimate of Quantities

Island Shoreline Lengths -- at elevation 600.00

Breakwater	2,500 feet
Crescent	2,635 feet
Plover	1,257 feet

Volume* of Fill

Breakwater Islands	61,600 c.y.
Crescent Island	63,800 c.y.
Plover Island	57,100 c.y.
Cross-Channel Deep Hole at elev. 594.0	970,000 c.y.

Total Volume* Final Drawing

3-Breakwater Islands	184,800 c.y.
3-Crescent Islands	191,400 c.y.
2-Plover Islands	114,200 c.y.
1-H island	20,000 c.y.
Addition to Interstate Island	50,000
Deep Hole @ 594.0	970,000 c.y.
Total Volume Final Plan	1,530,400 c.y.

say . . . 1.5 million cubic yards

*no adjustment applied for swell or compaction.

NWRPC
Sept. 91

F. Construction Cost Estimate

Breakwater Island

Earthwork	61,600 c.y. @	$5.00	$308,000
Armor Layer	2,978 c.y. @	35.00	104,230
Under Layer	1,915 c.y. @	20.00	38,300
Geotextile	6,382 sq.yd. @	3.00	19,146
Total Construction Cost each			$469,676

Crescent Island

Earthwork	63,800	$5.00	$319,000
Armor Layer	3,200	35.00	112,000
Under Layer	2,060	20.00	41,200
Geotextile	6,870	3.00	20,610
Total Construction Cost each			$492,810

Plover Island (Type 1) No sheet pile

Earthwork	57,100	$5.00	$285,500
Armor Layer	2,613 c.y.	35.00	91,455
Under Layer	1,680 c.y.	20.00	33,600
Geotextile	5,600 sq.yd.	3.00	16,800
Total Construction Cost each			$426,855

Deep Hole

Earthwork	970,000 c.y. @	$2.25	$2,182,500

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G. Study Findings

1. The depths, size and configuration of the submerged flat area near Interstate Island, located in near the center of the Duluth/Superior Harbor west of the main span of the Blatnik Bridge, does provide a feasible location for the construction of manmade islands.

2. The construction of these islands have great probability of increasing the value of natural habitat, specifically to:

   a. Create 50-100 acres of aquatic wetlands to support of juvenile fish of approximately 50 species.

   b. Creation of up to four miles of additional new shoreline, which would replace much of the shoreline lost from manmade activities over the past 100 years.

   c. Provide potential habitat for the piping plover, an endangered specie.

   d. Provide a nesting area for terns and other waterbirds.

   e. Provide temporary resting and feeding area for migratory waterfowl.

3. The site can provide for beneficial reuse of dredged material. Both contaminated and uncontaminated dredged material have potential to be used economically at this site.

4. The utilization of demolition material from the Blatnik Bridge deck replacement project as riprap armor does <u>not</u> appear feasible.

H. Recommendations

1. Investigation into construction of artificial islands and the filling the Deep Hole should be continued into a design stage.

2. Substantially more sub-surface exploration is needed in both the submerged flat area, as well as candidate dredged material.

3. Environmental studies, including an environmental assessment, should be prepared.

4. A title search and stub abstract should be prepared for the Wisconsin portion of the area to determine riparian owners and rights, if any.

5. U.S. Army Corps of Engineers should take the lead in further detailed evaluation of the potentials of this site. Since the site is located in two states and the COE maintenance dredging program is a likely implementor of this project, it seems logical that the COE should take the lead with the states of Minnesota and Wisconsin.

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V. APPENDICES

Appendix A.

List of Wildlife Species

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Brule Area Headquarters
P.O. Box 125
Brule, WI 54820-0125
715/372-4866

Carroll D. Besadny
Secretary

January 24, 1991

RECEIVED
FEB 4 1991
NORTHWEST REGIONAL PLANNING
302 Walnut Street
Spooner, WI 54801

File Ref: 2300
SLR/WCM

Anthony A. Wilhelm
Northwest Regional Planning Commission
302 Walnut Street
Spooner, WI 54801

RE: WCMP: Cross Channel Deep Hole - Interstate Island Design Investigations

Dear Tony:

Here is the wildlife information you requested regarding the above project.

The wildlife species listed are those which could <u>potentially</u> benefit from the creation of certain types of habitats in the St. Louis River. The interpretation of "benefit" is very broad. The species listed are ones which might, at sometime, use the created habitats. Use of the created habitats would vary greatly by species from breeding and young rearing, to feeding, to resting and shelter, etc.

Since the types and amounts of habitats, as well as their distribution that would be created under this proposal has not yet been determined, it is very likely that some of the species on these lists may not benefit from the proposal, should it be implemented, and that some species not on this list might benefit. The species list is based on the creation of the following types of habitats:

1.) Islands with sand/pebbly substrate and only sparse vegetation.

2.) Islands vegetated with a wide variety of herbaceous and shrubby woody vegetation.

3.) Shallow water areas with submergent, floating, and/or emergent aquatic vegetation.

4.) Mud flats, sand flats, and sandy beaches.

Endangered and threatened species are denoted by (E) and (T(respectively.

EARTH YEAR
WISCONSIN
1970 April 22 1990

If you have any questions about this information, please contact me.

Sincerely,

Fred Strand

Fred Strand
Area Wildlife Manager

FCS:b

WM8B1522.FCS

BIRDS:

Horned Grebe
Eared Grebe
Pied-billed Grebe
Double-crested Cormorant
Least Bittern
American Bittern
Black-crowned Night-heron
Green-backed Heron
Great Egret (T)
Great Blue Heron
Tundra Swan
Trumpeter Swan (E)
Snow Goose
Canada Goose
Mallard
American Black Duck
Gadwall
Green-winged Teal
American Widgeon
Northern Pintail
Northern Shoveler
Blue-winged Teal
Ruddy Duck
Wood Duck
Canvasback
Redhead
Ring-necked Duck
Greater Scaup
Lesser Scaup
Common Goldeneye
Bufflehead
Common Merganser
Red-breasted Merganser
Hooded Merganser
Virginia Rail
Sora
Yellow Rail
American Coot
Piping Plover (E)
Semipalmated Plover
Killdeer
Black-billed Plover
Lesser Golden Plover
Marbled Godwit
Hudsonian Godwit
Whimbrel
Willet
Greater Yellowlegs
Lessor Yellowlegs
Solitary Sandpiper
Spotted Sandpiper
Wilson's Phalarope
Short-billed Dowitcher
Long-billed Dowitcher
Stilt Sandpiper
Common Snipe
American Woodcock
Ruddy Turnstone
Red Knot
Dunlin
Sanderling
Semipalmated Sandpiper
Western Sandpiper
Least Sandpiper
White-rumped Sandpiper
Baird's Sandpiper
Pectoral Sandpiper
Buff-breasted Sandpiper
Franklin's Gull
Bonaparte's Gull
Ring-billed Gull
Herring Gull
Common Tern (E)
Forster's Tern (E)
Black Tern
Caspian Tern (E)
Bald Eagle (T)
Northern Harrier
Rough-legged Hawk
Merlin
Peregrine Falcon (E)
Gyrfalcon
Rock Dove
Mouring Dove
Short-eared Owl
Great Horned Owl
Snowy Owl
Common Nighthawk
Belted Kingfisher
Eastern Kingbird
Least Flycatcher
Alder Flycatcher
Horned Lark
Tree Swallow
Northern Rough-winged Swallow
Cliff Swallow
Barn Swallow
Blue Jay
Gray Jay
American Crow
House Wren
Marsh Wren
Sedge Wren
Eastern Bluebird

BIRDS (continued)

American Robin
Loggerhead Shrike (E)
Northern Shrike
American Pipit
Golden-winged Warbler
Chestnut-sided Warbler
Northern Waterthrush
Wilson's Warbler
Indigo Bunting
American tree Sparrow
Song Sparrow
Field Sparrow
Dark-eyed Junco
White-throated Sparrow
Swamp Sparrow
Lapland Longspur
Snow Bunting
Yellow-headed Blackbird
Red-winged Blackbird
Brewer's Blackbird
House Sparrow
American Goldfinch
Common Redpoll
Hoary Redpoll

Mammals:

Water Shrew
Short-tailed Shrew
Star-nosed Mole
Snowshoe Hare
Eastern Cottontail Rabbit
Beaver
White-footed Mouse
Meadow Vole
Muskrat
Norway Rat
House Mouse
Raccoon
Long-tailed Weasel
Mink
Striped Skunk
Otter

Amphibians and Reptiles:

Mudpuppy
American Toad
Green Frog
Leopard Frog
Snapping Turtle
Painted Turtle
Eastern Garter Snake

Appendix B.

Wilhelm Engineering Report

PRELIMINARY ENGINEERING REPORT
FOR
CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND
DESIGN INVESTIGATIONS

WEC Project No. 7009
Date of Issue: September 20, 1991

Prepared by

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PRELIMINARY ENGINEERING REPORT
for
CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND
DESIGN INVESTIGATIONS

INTRODUCTION

The purpose of this report is to analyze preliminary design concepts for wildlife habitat enhancement near Interstate Island in the Duluth/Superior harbor. The design concept consists of man-made low profile islands constructed from dredged materials. These islands would surround and shelter a shallow wetland of approximately 140 acres, as shown in Figures 3 and 4.

SCOPE OF INVESTIGATION

Wilhelm Engineering prepared this report as a sub-consultant to Northwest Regional Planning Commission. Tasks performed by Wilhelm Engineering were:

- Analysis of site wind and wave climate.
- Review island cross section design, including riprap sizing, wave runup, and slope stability.
- Slope stability analysis of adjacent dredged navigation channels.

STUDY TECHNIQUES

DESIGN DRAWINGS

Drawings for this report were produced using AutoCAD rel. 10 computer-aided drafting software. Base drawings of the project site and proposed layouts were provided in AutoCAD format by NWRPC and edited as required.

DESIGN WAVE ESTIMATES

Wave height, length, and period were estimated using the formulas and charts presented in the U.S. Army Corps of Engineers SHORE PROTECTION MANUAL (SPM) 1984. Design waves were based on simple fetch distances and wind-stress factors.

ESTIMATION OF SURFACE WINDS FOR WAVE PREDICTION

The simplified wave prediction formulas require an estimate of surface windspeed, direction, and duration which will provide the energy needed to develop the wave field.

The U.S. Weather Station is located at the Duluth International Airport. This location is six miles from the harbor and 880 feet above lake level. Winds recorded at this station are not representative of the conditions in the harbor.

The National Oceanic and Atmospheric Administration (NOAA) publication SUMMARY OF SYNOPTIC METEOROLOGICAL OBSERVATIONS FOR GREAT LAKES AREAS, (SSMO) Volume 4, Lake Superior, is frequently used as a source of wind and wave data for Lake Superior sites. Data in this publication was collected and compiled for the western part of Lake Superior during the period 1963 through 1973 from observations made by ships in passage. This data covers a large area of the open waters of Lake Superior and so was considered not representative of the conditions within the confines of the Duluth harbor.

Wind velocities recorded by the U.S. Coast Guard Station on Minnesota Point from 1954 through 1971 are considered to be the best representative data available for this site. Therefore this data was used to forecast waves for the project site (Figure 1).

WAVE DIFFRACTION AND BREAKING WAVES

Waves are a major factor in determining layout geometry, and structural design of protective islands in the harbor. Characteristics of wave mechanics, diffraction, and breaking waves were established using the methods and techniques found in Chapter 2, MECHANICS OF WAVE MOTION of the SHORE PROTECTION MANUAL published by the Coastal Engineering Research Center, Department of the Army, Corps of Engineers.

WAVE FORCES AND STRUCTURAL DESIGN

The preliminary design and performance of the rubble-mound slope protection was established using the methods and techniques found in Chapter 7, STRUCTURAL DESIGN: PHYSICAL FACTORS of the SHORE PROTECTION MANUAL published by the Coastal Engineering Research Center, Department of the Army, Corps of Engineers. The following design factors were included; wave characteristics, wave runup, overtopping and transmission, breaking and non-breaking wave forces, stability of rubble structures, stability of rubble foundations and toe protection.

SLOPE STABILITY

Stability of the navigation channel side slopes was evaluated to determine how close the islands could be placed to the navigation channels. These calculations were done by the Method of Slices using a Lotus 123 spreadsheet. Based upon soil boring data provided by the Corps of Engineers, the soils in the channel side slopes and beneath the proposed islands were assumed to be silty sand (SM) or Silt (ML) soils. Saturated density was assumed to be 120 pcf, buoyant density to be about 58 pcf and friction angle to be a maximum of 25 degrees. Figures 5 through 8 depict four slope stability calculation trials representative of the assumed conditions.

STUDY RESULTS AND DISCUSSION

DESIGN RECURRENCE FREQUENCY

The selection of a design recurrence frequency is primarily based on the potential for failure of the type of structure proposed as well as the potential for damage to property shoreward of the structure. There are no man-made structures or facilities susceptible to storm damage proposed for this project, and therefore the potential for property damage is minimal. Rubble mound type shore protection is proposed for this project. History has shown that when structures of this type are subjected to unusually large wave forces, greater than the design recurrence interval for which they are intended, the potential for catastrophic failure is minimal. Repairs are relatively simple and low cost, by relocating or replacing displaces armor units. It is therefore acceptable to design the shore protection for a more frequent storm event than if a more rigid type of shore protection structure was proposed.

Design recurrence frequencies of five years (20% exceedence frequency) and twenty years (5% exceedence frequency) were selected to represent an acceptable range of risk.

ESTIMATION OF SURFACE WINDS FOR WAVE PREDICTION

From the U.S. Coast Guard wind data in Figure 1, a 5 year wind velocity is 35 MPH, and a 20 year wind velocity is 42 MPH. For comparison, a 40 year wind velocity is 45 MPH.

Storm records available from the records of the U.S. Weather Station when it was located in downtown Duluth (1915-1951) indicate the predominant storm directions were northeast and northwest. Minor storm occurrences were from the west, southwest, and north. The south through east directions were relatively free of major storms. These records also show that the most frequent storm winds occurred during the months of November through April. During much of this period the harbor is covered by ice and is not susceptible to wind-driven waves.

For the design shown in Figure 2, a 20-year recurrence interval was used.

DESIGN WAVE ESTIMATES

For the purposes of this preliminary evaluation, the design wind velocities were applied to all directions. The effects of ice cover were neglected. Tables 1, 2 and 3 present shallow water wind-driven wave forecasts in 10 degree increments for 5-year, 20-year and 40-year recurrence intervals.

In addition to wind-driven waves, this site is also subject to the wake waves from passing watercraft, ranging from large (600' to 1000' long) bulk cargo vessels to tugboats and tourist cruisers to smaller pleasure craft. In addition to wake waves, the 1000 foot bulk cargo vessels frequenting this harbor generate a displacement wave, even when moving slowly.

An engineering design report prepared by the U.S. Army Corps of Engineers for the Erie Pier Confined Disposal Facility determined that the maximum ship generated wave height in the Duluth harbor is 2.4 feet, and that this wave would occur in phase with and augment wind driven waves. This wave height seems reasonable, but there are other factors that should be considered. While wake waves could at times occur in phase and with the same period as wind-driven waves, they would most often be out of phase, and have a different period. It must also be recognized that a ship generated wave is of very short duration, usually a single large wave followed by a few waves of successively lesser height. Therefore, we conclude that combining ship generated waves with wind-driven waves is not appropriate for rubble mound shore protection design on this site.

SELECTION OF DESIGN WAVES

The two highest design waves were from azimuth 90 degrees (east) and azimuth 220 degrees (southwest). Wave heights were 2.5' and 2.6' respectively for a 40-year recurrence interval, 2.4' and 2.5' respectively for a 20-year recurrence interval, and 1.9' and 2.0' respectively for a 5-year recurrence interval. For design of rubble-mound shore protection, a design wave height of 2.5' was selected.

As a general rule, a wave begins breaking at a water depth of 1.3 times the wave height. Waves approaching this site all travel across a navigation channel in excess of 25 feet deep. Sounding data from the COE shows that the side slopes of these channels range from approximately two horizontal for each vertical unit of distance (2h:1v) to 8h:1v. There would be a short reach (100 feet or less) of shallower water between the toe of the structure and the upper edge of the channel excavation. According to the Duluth harbor chart and soundings provided by the U.S. Army Corps of Engineers, this depth immediately in front of the structures would be 5 to 6 feet. Maximum unbroken wave height would be (5' / 1.3) = 3.8', which is 50% higher than any design wave for this site. We therefore conclude that any design wave reaching the proposed structures will be unbroken.

DESIGN STILL-WATER ELEVATION

Lake Superior is subject to a consistent seasonal rise and fall in water surface elevation. The amount of this seasonal fluctuation varies from year to year. For the period 1900 to 1970, the average fluctuation was 1.10 feet. For the period 1900 to 1986, the record maximum monthly mean water level was elevation 602.2 I.G.L.D. and the record minimum monthly mean water level was 598.0 I.G.L.D.

In addition to annual fluctuation, there are also short term oscillations generally referred to as wind setup and seiche, or simply as short term rise. These oscillations are caused by the differential atmospheric pressures and by the tractive force of the wind blowing over the water surface. Changes of this type can be up to 2 feet but seldom exceed 1 foot above or below the normal level.

In 1901, the U.S. Lake Survey adopted reference planes for use in it's charts. The planes were called "standard low water" and were selected so that their elevations would be lower than any stage that might be expected to occur during the navigation season. These planes are now called the "low water datums" (LWD). For Lake Superior, the level is set at 600.0 International Great Lakes Datum, 1955 (I.G.L.D. 1955).

For the recording station at Duluth, the 20 year design maximum water surface level was computed in the following manner:

5 Year Mean Monthly Level	601.9
+ 4 Year Short Term Rise	+ 1.4

	603.3 (I.G.L.D.)

The design minimum water surface level is low water datum 600.0 (I.G.L.D).

RUBBLE-MOUND DESIGN

A three-layer section design of the rubble-mound shore protection was used. This type of design consists of a core or bedding layer, covered by a secondary underlayer, covered by the primary armor layer. All of these layers are composed of rough, angular quarrystone carefully placed in such a manner that the stones interlock. The underlying layers of rock are sized to prevent pulling through the overlayer by wave action. The stones of the primary armor layer are of sufficient mass to resist displacement by wave action.

Figure 2 shows the recommended sizing and thickness of the stone layers. In place of the core layer, we recommend using a geotextile filter fabric to prevent the dredged material core from washing through the rock.

WAVE RUNUP AND OVERTOPPING

Wave runup on the proposed 2:1 rubble-mound slope was calculated using a design wave height of 2.5 feet, and the design maximum still water elevation of 603.3 feet. The calculated runup elevation is 605.4', which is 0.6' below the structure crest elevation of 606.0.

ICE FORCES

Normally, shore structures are subject to wave forces comparable in magnitude to the maximum probable pressure exerted on the structure by an ice sheet. Since maximum wave forces and maximum ice pressure cannot occur at the same time, no special allowance is usually made for stability to resist ice thrust.

Floating ice fields when driven by strong winds or currents can pile up against a structure in large ice packs. On a sloped rubble-mound structure these ice packs can by driven up the slope and overtop the structure.

In isolated incidents ice formations can cause minor damage to rubble-mound structures, by displacing a few of the armor stones. However, the effects of ice are more often found to be beneficial. In most cases ice build-up does no harm to the structure and actually provides protection against severe winter waves.

WAVE DIFFRACTION

Diffraction is the reduction in wave height and bending of waves crests that occurs when water waves pass into the lee of a barrier. Figures 3 and 4 show calculated diffraction patterns in the project area for the two worst-case approach wave conditions. Note that the lines shown in the figures are lines of equal wave <u>height</u> and do not represent direction of wave crests.

DREDGED CHANNEL SLOPE STABILITY

Sounding data provided by the Corps of Engineers showed that channel side slopes vary from 2h:1v to 8h:1v. These two slopes were evaluated to analyze the range of existing conditions. The Stability Trial 1 sketch in Figure 5 shows a 2h:1v slope. The calculated factor of safety is 0.54 for a friction angle of 25 degrees and a 60' radius failure surface. The Stability Trial 2 sketch in Figure 6 shows a 8h:1v slope. The factor of safety is 2.44 for a 25 degree friction angle and 200' radius failure surface. Sensitivity analysis showed that if the assumed friction angle is reduced to as low as 15 degrees, the 8h:1v slope still has a 1.40 factor of safety. This is close to the value of 1.5, normally recommended as a minimum factor of safety for slope stability on designed projects.

After analyzing the range of stability for existing conditions, the proposed man-made island was placed at the top of an assumed 8h:1v slope, as shown in the Stability Trial 3 sketch of Figure 7. This resulted in a safety factor of 1.57 for a 25 degree friction angle and a 250' failure surface radius. If the angle is reduced to 20 degrees, the safety factor is only 1.23.

In order to further evaluate the proposed design concept, the proposed island was placed at the top of a 5h:1v slope, as shown by the Stability Trial 4 sketch in Figure 8. This results in a safety factor of 1.08, which is too low. Sensitivity analysis demonstrated that the friction angle would have to be in the range of 32-33 degrees to yield a safety factor of 1.5. Typically, the dredge materials in this harbor are not very likely to have that high of friction angle.

These preliminary stability analyses indicate that the channel side slopes will probably need to be about 8h:1v in order to be stable with the proposed man-made island in place. We conclude that the outside toe of the islands will need to be about 150' to 175' back from the toe of the channel side slopes. Actual site specific soil borings and test data in the deposits under the proposed island sites must be done to verify the soil parameters assumed for this conceptual analysis. Revised soil parameters may lead to changes in these preliminary conclusions and recommendations.

CONCLUSIONS

In summary this preliminary study has shown that the proposed design concepts to improve wildlife habitat near Interstate Island in the Duluth/Superior Harbor appear to be technically feasible, based upon data available at this time. More specifically, we have determined:

- A design recurrence frequency in the range of 5-20 years is adequate.
- A design wave height of 2.5' for a 20-year recurrence interval.
- The proposed rubble-mound shore protection is a proven, easily maintained type of structure with a natural appearance.
- The calculated wave runup elevation is 605.4'.
- The rubble-mound shore protection crest elevation should be at least 606.0'.
- Channel side slopes on the order of 8h:1v appear to be necessary in order to be stable with the proposed man-made islands in place.

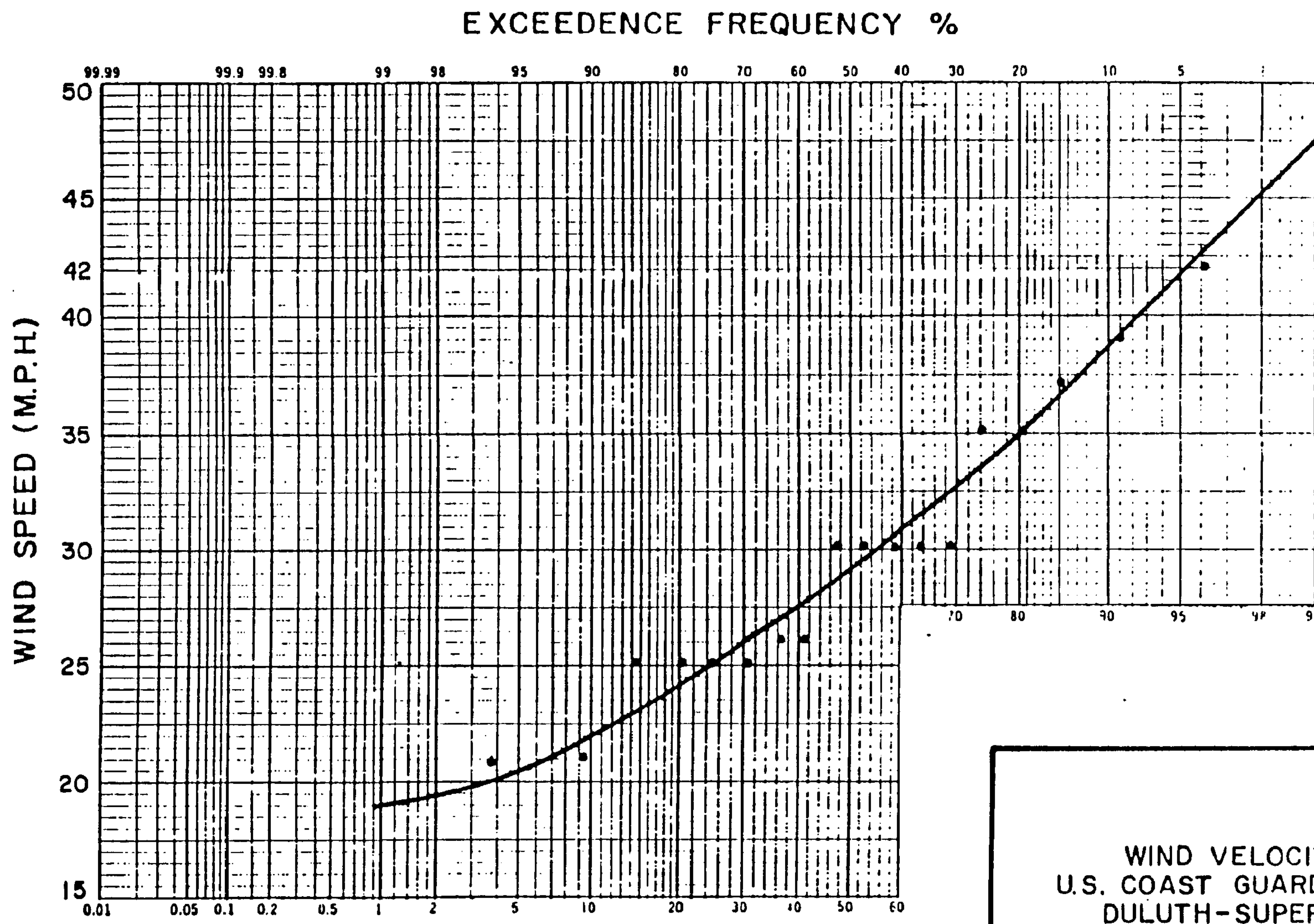
LIMITATIONS OF STUDY AND REPORT

This report represents a preliminary engineering concept analysis and design evaluation and should not be the basis for actual construction. It is recommended that if this project proceeds to design, a consultant be retained to review the findings of this study, perform a detailed engineering analysis of the preferred design, and prepare detailed construction plans, specifications, and estimates.

The conclusions and recommendations contained herein were based upon the applicable standards of our profession at the time this report was prepared. Copies of this report are furnished only to provide the factual data summarized in the report.

This report, consisting of 7 pages, tables, figures, and letter of transmittal has been prepared for the exclusive use of Northwest Regional Planning Commission and Wisconsin Coastal Management Program for specific application to the Cross Channel Deep Hole - Interstate Island Design Investigations.

END OF REPORT



NOTE: WIND DURATIONS ARE 3 HOUR PERIODS (MIN.)

WIND VELOCITY
U.S. COAST GUARD DATA
DULUTH-SUPERIOR
1954 THRU 1971
ST. PAUL, MINN. DISTRICT
FILE NO. LS38-R-5/22

FIGURE 1

TABLE 1
Shallow water wave forecast
Cross-channel Deep Hole Design Investigation

5-Year Recurrence Interval
Wind speed = 35 MPH
Wind-stress factor = 46.5 MPH

True Azimuth (deg.)	Simple Fetch (ft.)	Avg. Depth (ft.)	Wave Height (ft.)	Wave Period (sec.)	Min. Duration (hours)	Wave Length (ft.)
0	4200	25	1.2	1.8	0.2	16.6
10	3525	25	1.1	1.7	0.2	14.8
20	2900	25	1.0	1.6	0.2	13.1
30	2525	25	0.9	1.5	0.2	11.5
40	2475	25	0.9	1.5	0.2	11.5
50	2525	25	0.9	1.5	0.2	11.5
60	2625	25	1.0	1.6	0.2	13.1
70	3075	25	1.0	1.6	0.2	13.1
80	3250	25	1.0	1.6	0.2	13.1
90	11175	20	1.9	2.4	0.5	29.5
100	3825	25	1.2	1.7	0.2	14.8
110	3175	25	1.0	1.6	0.2	13.1
120	6250	25	1.5	2.0	0.3	20.5
130	2800	20	1.0	1.6	0.2	13.1
140	2400	25	0.9	1.5	0.1	11.5
150	2775	25	1.0	1.6	0.2	13.1
160	2225	25	0.9	1.5	0.1	11.5
170	2300	25	0.9	1.5	0.1	11.5
180	2425	25	0.9	1.5	0.1	11.5
190	2725	25	1.0	1.6	0.2	13.1
200	3100	25	1.0	1.6	0.2	13.1
210	3950	25	1.2	1.7	0.2	14.8
220	18150	10	2.0	2.7	0.6	37.3
230	11225	15	1.8	2.4	0.5	29.5
240	12425	20	2.0	2.5	0.5	32.0
250	4825	25	1.2	1.8	0.3	16.6
260	4350	25	1.2	1.8	0.3	16.6
270	3500	25	1.1	1.7	0.2	14.8
280	3550	15	1.1	1.7	0.2	14.8
290	2125	25	0.8	1.5	0.1	11.5
300	2625	25	1.0	1.5	0.2	11.5
310	4025	5	1.0	1.7	0.2	14.8
320	3775	5	1.0	1.7	0.2	14.8
330	3850	5	1.0	1.7	0.2	14.8
340	4700	5	1.1	1.8	0.2	16.6
350	5450	10	1.3	1.9	0.3	18.5

TABLE 2
Shallow water wave forecast
Cross-channel Deep Hole Design Investigation

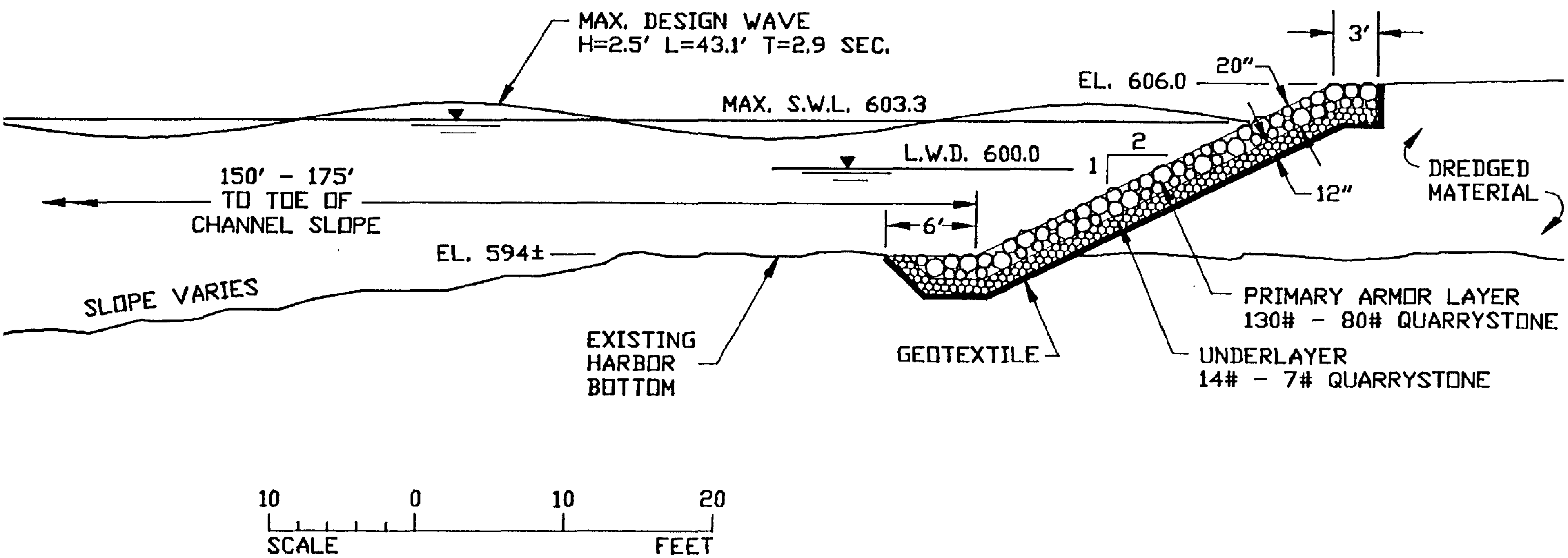
20-Year Recurrence Interval
Wind speed = 42 MPH
Wind-stress factor = 56.4 MPH

True Azimuth (deg.)	Simple Fetch (ft.)	Avg. Depth (ft.)	Wave Height (ft.)	Wave Period (sec.)	Min. Duration (hours)	Wave Length (ft.)
0	4200	25	1.5	2.0	0.2	20.5
10	3525	25	1.4	1.8	0.2	16.6
20	2900	25	1.3	1.8	0.1	16.6
30	2525	25	1.2	1.7	0.1	14.8
40	2475	25	1.2	1.7	0.1	14.8
50	2525	25	1.2	1.7	0.1	14.8
60	2625	25	1.3	1.8	0.1	16.6
70	3075	25	1.3	1.8	0.1	16.6
80	3250	25	1.4	1.8	0.2	16.6
90	11175	20	2.4	2.6	0.4	34.6
100	3825	25	1.5	1.9	0.2	18.5
110	3175	25	1.3	1.8	0.1	16.6
120	6250	25	1.8	2.2	0.3	24.8
130	2800	20	1.3	1.7	0.1	14.8
140	2400	25	1.2	1.6	0.1	13.1
150	2775	25	1.3	1.8	0.1	16.6
160	2225	25	1.1	1.6	0.1	13.1
170	2300	25	1.2	1.6	0.1	13.1
180	2425	25	1.2	1.7	0.1	14.8
190	2725	25	1.3	1.8	0.1	16.6
200	3100	25	1.3	1.8	0.1	16.6
210	3950	25	1.5	1.9	0.2	18.5
220	18150	10	2.5	2.9	0.5	43.1
230	11225	15	2.3	2.6	0.4	34.6
240	12425	20	2.5	2.7	0.4	37.3
250	4825	25	1.5	2.0	0.2	20.5
260	4350	25	1.5	2.0	0.2	20.5
270	3500	25	1.4	1.8	0.2	16.6
280	3550	15	1.4	1.8	0.2	16.6
290	2125	25	1.0	1.5	0.1	11.5
300	2625	25	1.3	1.8	0.1	16.6
310	4025	5	1.3	1.8	0.2	16.6
320	3775	5	1.3	1.8	0.2	16.6
330	3850	5	1.3	1.8	0.2	16.6
340	4700	5	1.4	1.9	0.2	18.5
350	5450	10	1.6	2.0	0.2	20.5

TABLE 3
Shallow water wave forecast
Cross-channel Deep Hole Design Investigation

40-Year Recurrence Interval
Wind speed = 45 MPH
Wind-stress factor = 63.6 MPH

True Azimuth (deg.)	Simple Fetch (ft.)	Avg. Depth (ft.)	Wave Height (ft.)	Wave Period (sec.)	Min. Duration (hours)	Wave Length (ft.)
0	4200	25	1.6	2.0	0.2	20.5
10	3525	25	1.5	1.9	0.2	18.5
20	2900	25	1.4	1.8	0.1	16.6
30	2525	25	1.3	1.7	0.1	14.8
40	2475	25	1.3	1.7	0.1	14.8
50	2525	25	1.3	1.7	0.1	14.8
60	2625	25	1.3	1.7	0.1	14.8
70	3075	25	1.4	1.8	0.1	16.6
80	3250	25	1.5	1.9	0.2	18.5
90	11175	20	2.5	2.7	0.4	37.3
100	3825	25	1.5	1.9	0.2	18.5
110	3175	25	1.4	1.8	0.1	16.6
120	6250	25	2.0	2.3	0.3	27.1
130	2800	20	1.4	1.7	0.1	14.8
140	2400	25	1.3	1.7	0.1	14.8
150	2775	25	1.4	1.8	0.1	16.6
160	2225	25	1.2	1.6	0.1	13.1
170	2300	25	1.2	1.6	0.1	13.1
180	2425	25	1.3	1.7	0.1	14.8
190	2725	25	1.3	1.7	0.1	14.8
200	3100	25	1.4	1.8	0.1	16.6
210	3950	25	1.6	2.0	0.2	20.5
220	18150	10	2.6	2.9	0.5	43.1
230	11225	15	2.5	2.6	0.4	34.6
240	12425	20	2.7	2.8	0.4	40.1
250	4825	25	1.7	2.1	0.2	22.6
260	4350	25	1.6	2.0	0.2	20.5
270	3500	25	1.5	1.9	0.2	18.5
280	3550	15	1.5	1.9	0.2	18.5
290	2125	25	1.2	1.6	0.1	13.1
300	2625	25	1.3	1.7	0.1	14.8
310	4025	5	1.4	1.9	0.2	18.5
320	3775	5	1.3	1.8	0.2	16.6
330	3850	5	1.3	1.8	0.2	16.6
340	4700	5	1.5	2.0	0.2	20.5
350	5450	10	1.7	2.1	0.2	22.6



CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
RUBBLE-MOUND SLOPE PROTECTION

WILHELM ENGINEERING COMPANY, INC.

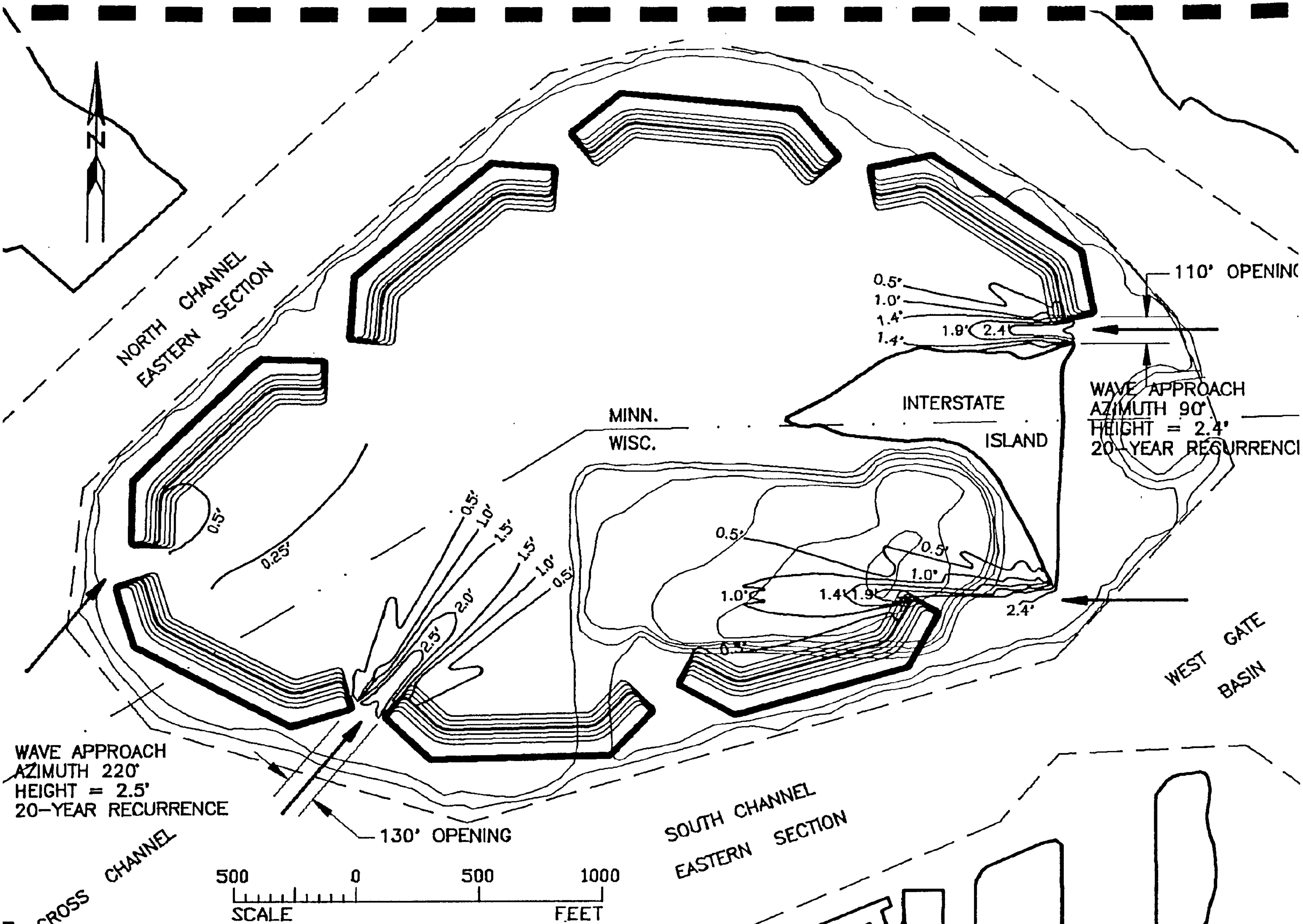
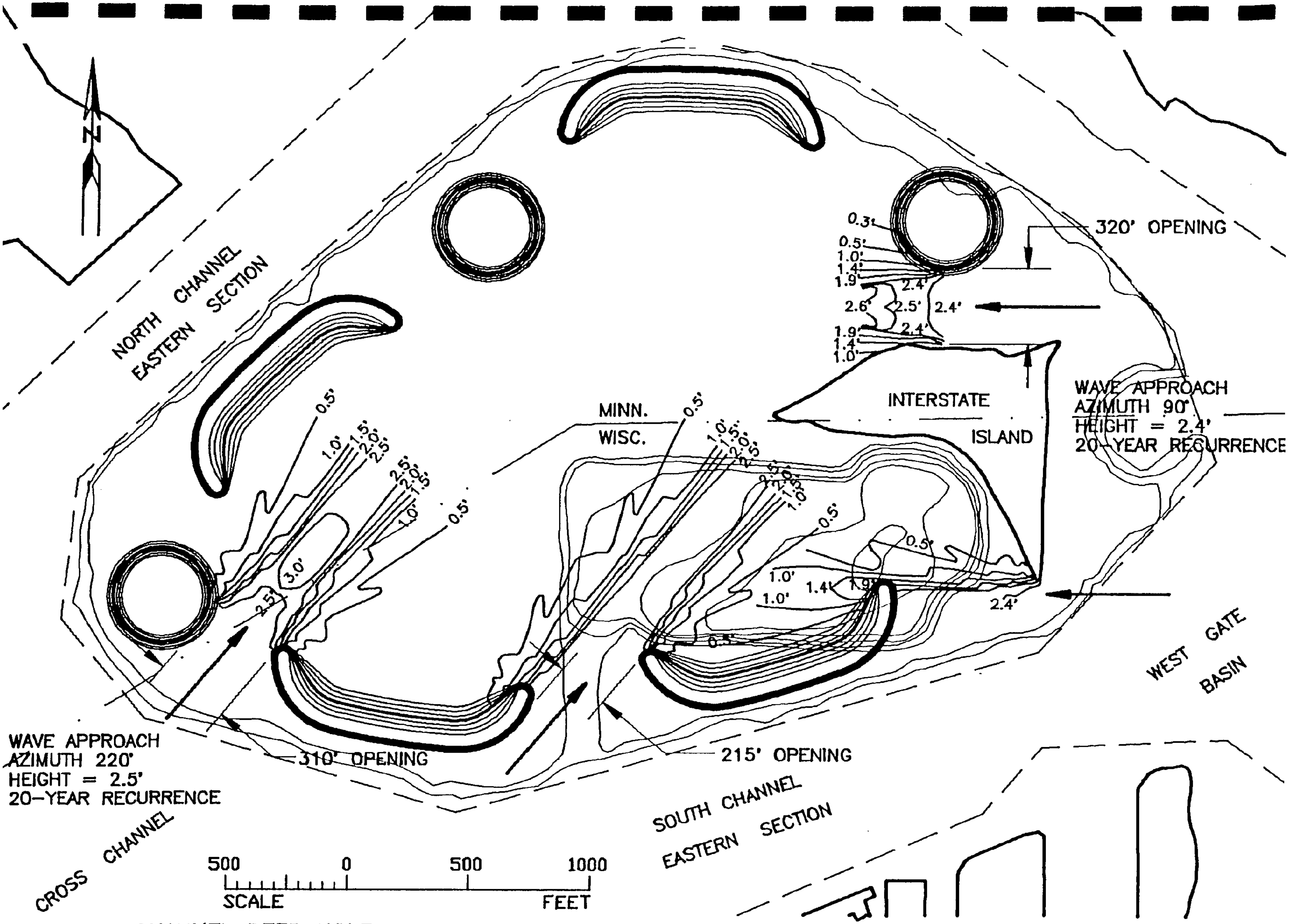


FIGURE 3

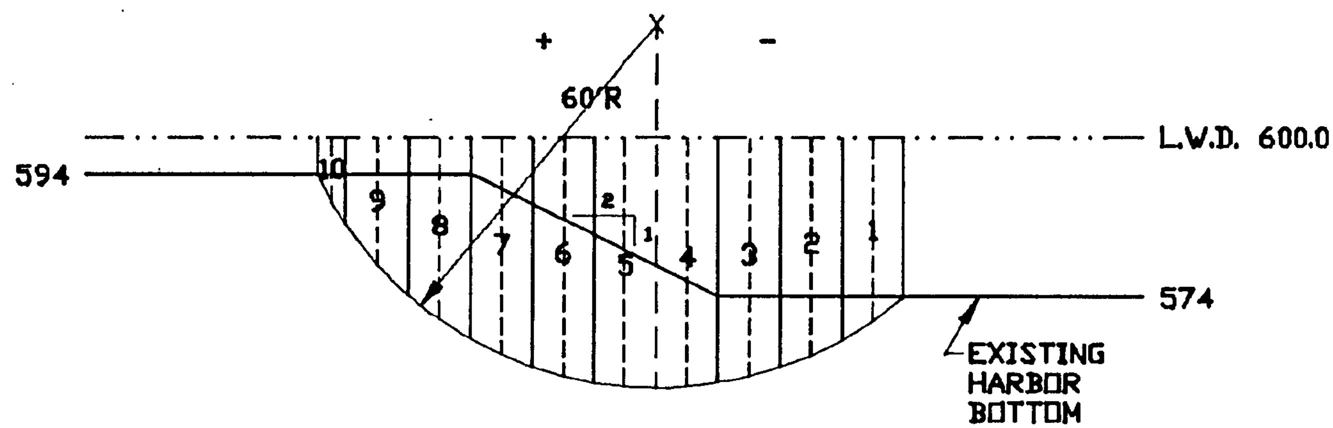
CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
WAVE DIFFRACTION DIAGRAMS – TRIAL PLAN 1

WILHELM ENGINEERING COMPANY, INC.



CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
WAVE DIFFRACTION DIAGRAMS - TRIAL PLAN 2

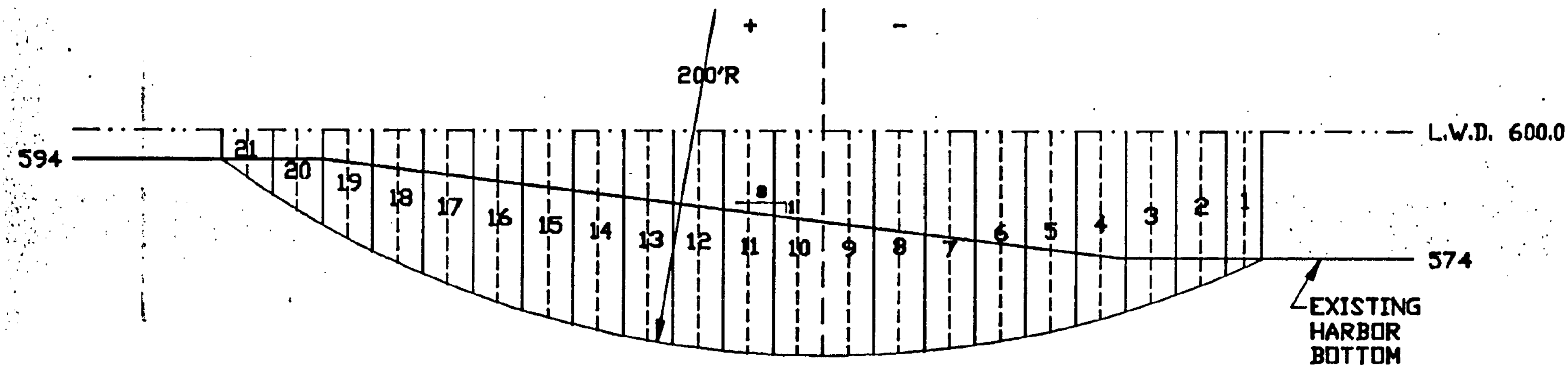
WILHELM ENGINEERING COMPANY, INC.



SCALE: 1" = 30'

CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
CHANNEL SLOPE STABILITY ANALYSIS – TRIAL 1

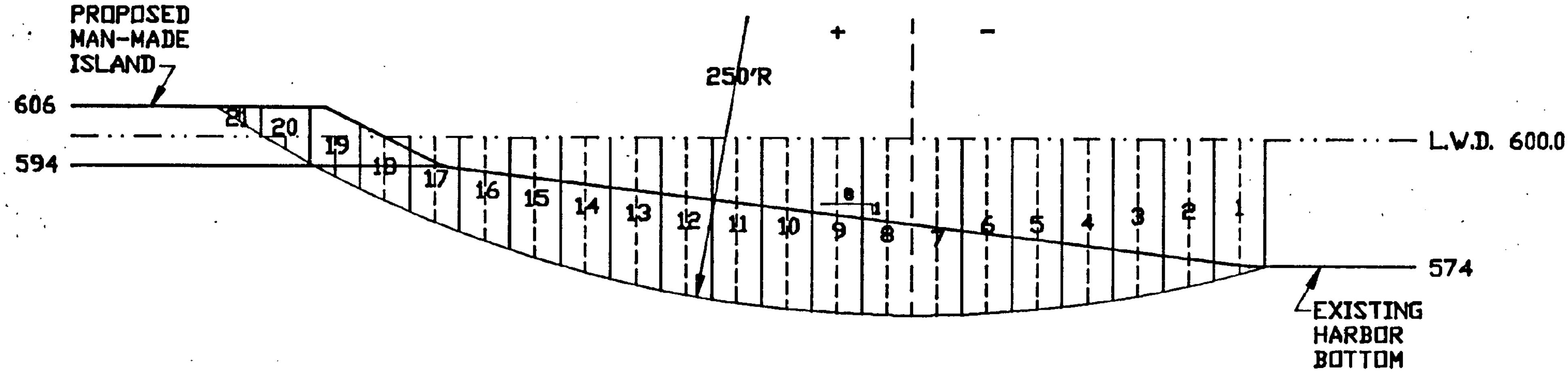
WILHELM ENGINEERING COMPANY, INC.
ASHLAND, WISCONSIN



SCALE: 1" = 30'

CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
CHANNEL SLOPE STABILITY ANALYSIS – TRIAL 2

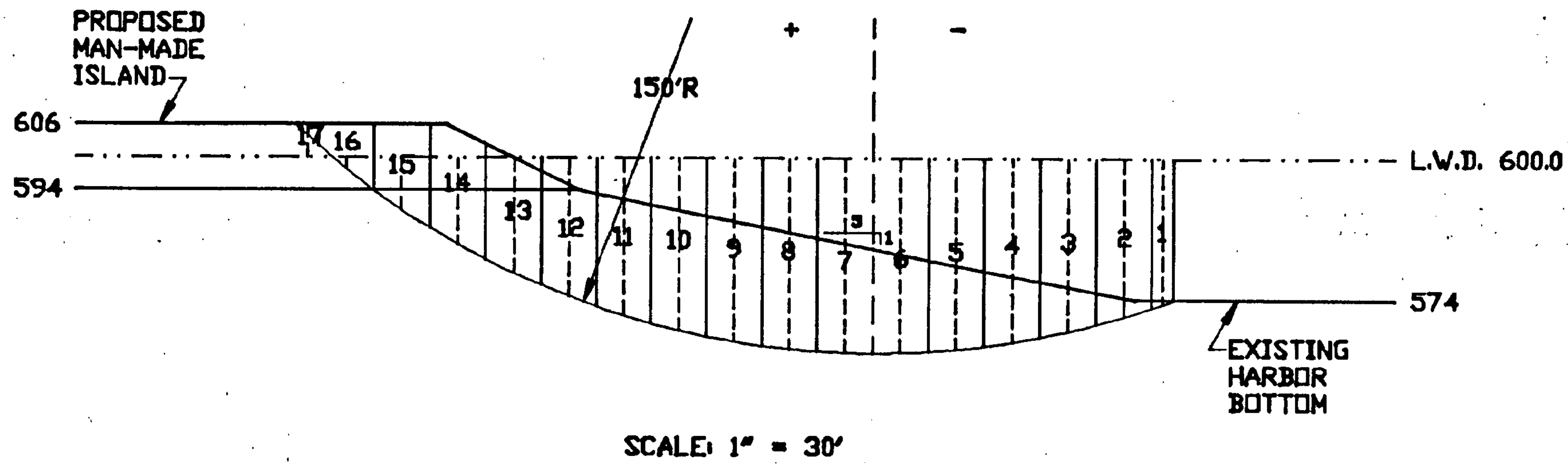
WILHELM ENGINEERING
COMPANY, INC.
ASHLAND WISCONSIN



SCALE: 1" = 30'

CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
CHANNEL SLOPE STABILITY ANALYSIS – TRIAL 3

WILHELM ENGINEERING COMPANY, INC.



CROSS CHANNEL DEEP HOLE
INTERSTATE ISLAND DESIGN INVESTIGATION
CHANNEL SLOPE STABILITY ANALYSIS – TRIAL 4

WILHELM ENGINEERING COMPANY, INC.
ASHLAND, WISCONSIN

Appendix C.

Estimate of Quantities

Wilhelm Engineering Company, Inc. Consulting Engineers
707 Main St. W. Ashland, Wisconsin 54806 (715) 682-8175 - FAX (715) 682-3911

CHECK ISLAND VOLUMES

NOTE: CRESCENT ISLAND DIMENSIONS BY NWRPC DID NOT CHECK. REDESIGNED ISLAND 1000' LONG X 250' WIDE

CRESCENT ISLAND:

AREA = 64,484 SQ.FT. @ EL. 606
AREA = 145,451 SQ.FT. @ EL. 600
AREA = 218,760 SQ.FT. @ EL. 594

(64,484 + 145,451) / 2 X 6' ÷ 27 = 23,326 CU.YD.
(145,451 + 218,760) / 2 X 6' ÷ 27 = 40,468 CU.YD.

63,794 CU.YD.

BREAKWATER ISLAND:

AREA = 58,321 SQ.FT. @ EL. 606
AREA = 219,017 SQ.FT. @ EL. 594

(58,321 + 219,017) / 2 X 12' ÷ 27 = 61,631 CU.YD.

PLOVER ISLAND:

NOTE: SLOPE SCALED APPROX. 5:1

AREA = 90,792 SQ.FT. @ EL. 606
AREA = 166,190 SQ.FT. @ EL. 594

(90,792 + 166,190) / 2 X 12' ÷ 27 = 57,107 CU.YD.

PROJECT CROSS CHANNEL DEEP HOLE PROJ. NO. 7009
SUBJECT CLIENT
COMP BY AS DATE 9/10/91 CKD BY DATE SHEET OF

Wilhelm Engineering Company, Inc. Consulting Engineers

707 Main St. W. Ashland, Wisconsin 54806 (715) 682-8175 - FAX (715) 682-3911

BREAKWATER ISLAND:

LENGTH OF SHORELINE AT EL. 600 = 2,506 LIN. FT.

SURFACE AREA ABOVE EL. 600 = 140,369 SQ. FT.

LIN. FT. OF RIPRAP = 1,436

ARMOR LAYER:
1,436' X 56 SQ. FT. ÷ 27 = 2,978 CU. YD.

UNDER LAYER:
1,436' X 36 SQ. FT. ÷ 27 = 1,915 CU. YD.

GEOTEXTILE:
1,436' X 40 LIN. FT. ÷ 9 = 6,382 SQ. YD.

PROJECT CROSS CHANNEL DEEP HOLE PROJ. NO. 7009

SUBJECT ______ CLIENT ______

COMP BY HAS DATE 10/1/91 CKD BY ______ DATE ______ SHEET ______ OF ______

Wilhelm Engineering Company, Inc. Consulting Engineers

707 Main St. W. Ashland, Wisconsin 54806 (715) 682-8175 - FAX (715) 682-3911

CRESCENT ISLAND:

LENGTH OF SHORELINE AT EL. 600 = 2,635 LIN. FT.

SURFACE AREA ABOVE EL. 600 = 145,450 SQ. FT.

LIN. FT. OF RIPRAP = 1,545

ARMOR LAYER:

1545' x 56 SQ.FT. ÷ 27 = 3,204 CU.YD.

UNDERLAYER:

1545' x 36 SQ.FT. ÷ 27 = 2,060 CU.YD.

GEOTEXTILE:

1545' x 40 LIN.FT. ÷ 9 = 6,867 SQ.YD.

PROJECT CROSS CHANNEL DEEP HOLE PROJ. NO. 7009

SUBJECT ____ CLIENT ____

COMP BY JAS DATE 9/10/91 CKD BY ____ DATE ____ SHEET ____ OF ____

Printing Plus, Ashland, WI

Wilhelm Engineering Company, Inc. Consulting Engineers
707 Main St. W. Ashland, Wisconsin 54806 (715) 682-8175 - FAX (715) 682-3911

PLOVER ISLAND:

LENGTH OF SHORELINE AT EL. 600 = 1,257 LIN. FT.

SURFACE AREA ABOVE EL. 600 = 125,664 SQ. FT.

LIN. FT. OF RIPRAP = 1,260

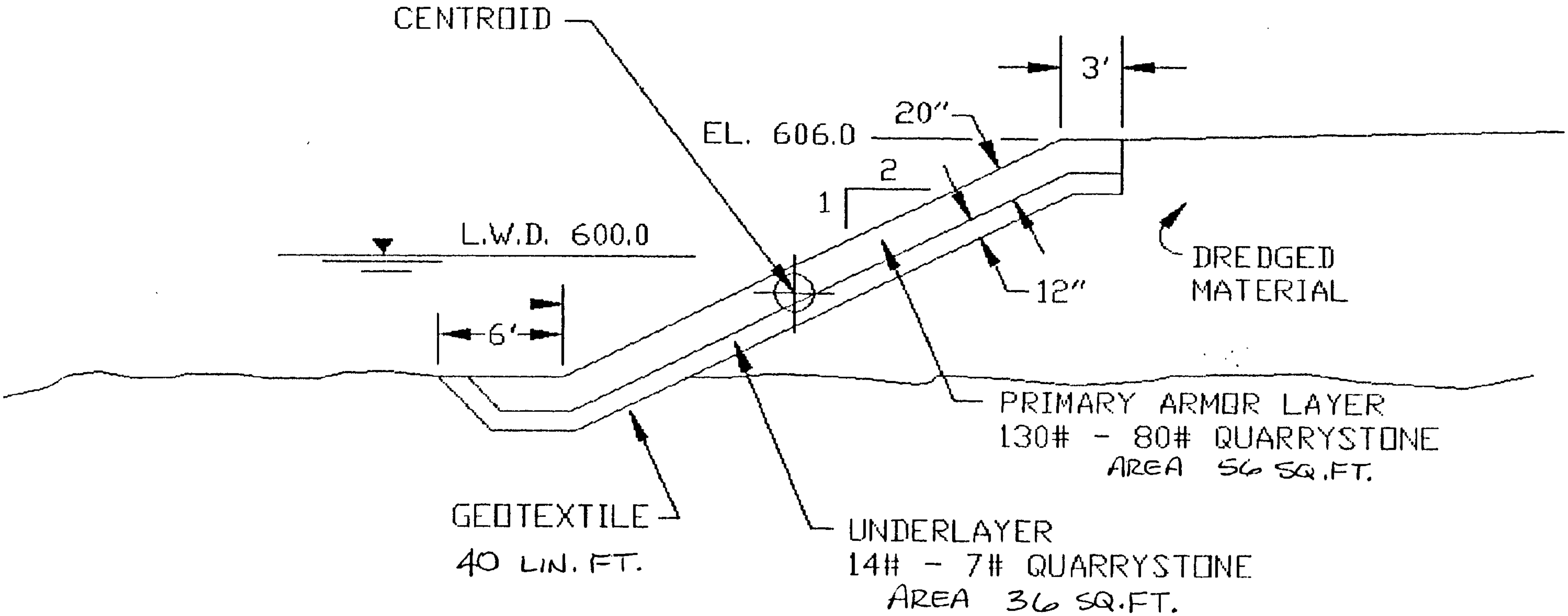
ARMOR LAYER:
1260' X 56 SQ.FT. ÷ 27 = 2,613 CU.YD.

UNDERLAYER:
1260' X 36 SQ.FT. ÷ 27 = 1,680 CU.YD.

GEOTEXTILE:
1260' X 40 LIN.FT. ÷ 9 = 5,600 SQ.YD.

PROJECT CROSS CHANNEL DEEP HOLE PROJ. NO. 7009
SUBJECT ______ CLIENT ______

COMP BY JAS DATE 10/1/91 CKD BY ______ DATE ______ SHEET ______ OF ______


CENTROID
3'
20"
EL. 606.0
2
1
12"
L.W.D. 600.0
6'
DREDGED MATERIAL
PRIMARY ARMOR LAYER
130# - 80# QUARRYSTONE
AREA 56 SQ.FT.
GEOTEXTILE
40 LIN. FT.
UNDERLAYER
14# - 7# QUARRYSTONE
AREA 36 SQ.FT.

Appendix D.

GME Report

PRELIMINARY FEASIBILITY ASSESSMENT OF
ARTIFICIAL ISLAND CONSTRUCTION
CROSS CHANNEL DEEP HOLE AND
SUBMERGED FLATS IN THE
DULUTH-SUPERIOR HARBOR
DULUTH, MINNESOTA/SUPERIOR, WISCONSIN
SUBMITTED TO
THE NORTHWEST REGIONAL PLANNING COMMISSION
BY
GME CONSULTANTS, INC.
GME PROJECT NO. D-1417
SEPTEMBER 30, 1991

INTRODUCTION

As stated in the document of November, 1989, prepared by the Northwest Regional Planning Commission (NWRPC) and titled "Superior Harbor Dredged Material Disposal Report," the existing Contained Disposal Facility (CDF) for the Duluth-Superior Harbor has a limited life. In 1989, it was estimated that this sole operational CDF, located in Duluth (Erie Pier), had approximately 1 to 2 years of remaining life expectancy, and that no CDFs were under design at that time. To maintain commercial shipping, the Ports of Duluth and Superior would require approximately 150,000 cubic yards of dredging annually, meaning that 150,000 cubic yards of dredged materials must be disposed of per year.

Current Wisconsin law and current Minnesota practice, require that dredged material be confined on land, and not disposed of in open water. The NWRPC has recommended that new sites or new methods must be identified which would meet the requirements of current and proposed State and Federal dredgings disposal regulations, in order to permit continued dredging. One alternative which is under consideration, is to fill the Cross Channel Deep Hole which lies to the southwest of Interstate Island, with dredged spoils. We understand that it is possible that this hole resulted from past dredging ("hydromining") to generate fill for the Seaway Port Authority of Duluth Marine Terminal. The volume of the hole has been computed at approximately 970,000 cubic yards. In addition to filling this hole with dredgings, the proposal further considers construction of artificial islands in the flats around the hole, for occupation by water fowl and fish habitat.

As outlined in our contract, the elements of this study are to include the following.

A. Conduct a literature search on the placement of dredging for island construction within Minnesota and Wisconsin Agency jurisdiction

B. Recommend construction methods for placement dredged material on 2:1 underwater slopes, and provide an estimate of the underwater natural angle of repose

C. Provide preliminary estimates of settlement of man-made islands constructed of dredged material

D. Discuss the use of geofabrics in containment of buried layers in the Deep Hole

E. Discuss the effectiveness of a cap of unpolluted materials to contain contaminated materials placed deep in the Cross Channel Hole

The purpose of this report is to identify topics which must be addressed pursuant to a design plan for island construction. This report is not to be construed as a design document of itself.

A. AGENCY LITERATURE SEARCH

We contacted the Wisconsin Department of Natural Resources (WDNR), the Minnesota Department of Natural Resources (MDNR), and the Minnesota Pollution Control Agency (MPCA), to inquire about literature available regarding the placement of dredged spoils in open water areas, and for island construction in open water areas. It is our understanding that the MPCA currently has no literature in terms of technical papers or position papers, regarding the use of dredging spoils placed in open water areas or for island construction.

We understand that in Minnesota, while the law does not currently completely forbid the placement of dredging spoils in open water areas, the current practice of the MPCA is not to allow this method of disposal. We were told there are no specific position papers or technical literature from the MDNR dealing with this topic.

In Wisconsin, since 1975, the placement of dredging spoils in open water areas has been prohibited by law and we understand there is no current literature available to indicate that this would change. Man-made islands were recently constructed in backwater areas of the Mississippi River near Winona, Minnesota, as part of a program to improve wildlife habitat. This was done under Corps of Engineers jurisdiction.

B. UNDERWATER SLOPES OF DREDGINGS

The placement of granular soils underwater results in a slope configuration which is dependent upon a number of factors. Primary determinants in the slope are the gradation of the material and the amount material passing the No. 200 sieve. The placement method can also affect the slope. These slopes can range from as steep as approximately 2:1 (2 units horizontal to 1 unit vertical) for very clean (less than about 2% passing the NO. 200 sieve) medium sand or sand and gravel, to as flat as 25:1, which would typically be expected for silty dredgings. The slopes could also be affected by the water currents in the area.

The writer has had experience with the use of fine to medium sand with less than 1% passing the No. 200 sieve, for placement as artificial island in backwater areas and in river currents. We have measured actual underwater slopes on the order of 3:1 to 5:1 in these conditions (Weaver Bottoms on the Mississippi River and in nearby backwater areas near Winona, Minnesota).

In order to construct a 2:1 underwater slope, it first would be necessary to determine the gradation of the dredgings to be placed. If the material is too fine, the construction of underwater slopes at the desired angle could require the placement of riprap embankments around the perimeter of the area where the dredgings are to be placed, in order to contain the dredgings. It would also be feasible to use a starter dike below the water, place the dredging in layers, and raise the dike elevation by bulldozing over the previous and over the dredgings. We strongly recommend that a geotechnical exploration program, with soil borings, laboratory testing, and analysis, be carried out to determine the stability of embankments built on or near the edge of the Hole.

Above the water level, the dredgings would reach an eventual slope equal to the angle of repose. However, hydraulically placed dredgings could run out to an initial slope flatter than the angle of repose. The slope above water can be shaped by conventional earth moving equipment such as bulldozers or front loaders, after completion of the placement.

C. SETTLEMENT OF MAN-MADE DREDGINGS ISLANDS

Four mechanisms control the volume change (densification) of dredgings placed underwater. These four mechanisms are in the order of occurrence:

1. Discrete settlement
2. Flocculent settlement
3. Zone settlement
4. Compression settlement, which transitions to consolidation

The factors controlling the post-placement settlement of the islands are those which effect the relative density to which the dredges spoils are placed. The more granular the dredgings are and the less amount of silt or clay content, the higher the initial relative density that is obtained without compaction. The gradation will also effect the rate at which the consolidation occurs.

For preliminary estimating purposes, we estimate that a fine sand or fine to medium sand with less than about 3% passing the No. 200 sieve could consolidate as much as 50% of the original height under its own weight, particularly when the dredgings break to the surface and the moist unit weight, as opposed to the buoyant unit weight, of dredgings is applied. A loosely deposited silty sand or sandy silt can become reduced in thickness, as much as half of its original height under its own weight. Water currents can also impact the amount of consolidation and the rate of consolidation of the dredgings.

There are methods available for underwater consolidation of granular soils which would be applicable to dredgings. "Surcharge," that is, building an island up above the planned final grade, could be used to force consolidation of the deeper dredges. Other alternatives would include vibro compaction which consists of lowering a large diameter vibratory probe into the granular soil below the water level, and dynamic compaction, which consists of repeated dropping of a heavy weight on the exposed surface. Dynamic compaction was successfully used to consolidate the soils of Barkers Island in Superior Harbor, an old dredgings disposal site, for the support of the hotel on a conventional spread footing foundation. This procedure was successfully achieved under the direction of the writer in 1979.

The densification of the dredgings would assist with the long-term volumetric disposal problem. Typically, a silty dredging spoil would require approximately 2 to 3 times the disposal volume as the in-place volume. For a granular dredging, up to 1.5 times the original in-place volume would be needed for disposal. Thus, consolidation of the dredgings in-place can provide for a longer term disposal operation.

D. GEOTEXTILES FOR CONTAINMENT

The use of geotextiles in containing dredgings disposed of underwater, has not been extensively studied or used in the United States. From personal contact with engineers involved in the manufacture of geofabrics and at the Corps of Engineers Waterways Experiment Station, we understand that there are a few contractors in Europe who have the expertise, but they have not yet shared the available information regarding the use of geotextiles because of the proprietary nature of their work. We understand that, at the present time, there is no literature available on the use of geofabrics for containing dredgings underwater.

The concepts being studied at the Waterways Experiment Station include the fabrication of geofabric "pillows" or "tubes" which are then filled with dredgings. To date, we understand they have not yet been used underwater for island construction. We understand that an experiment is currently underway at Gaylord Island in Mobile, Alabama, by the Corps of Engineers, for the use of these tubes to increase the height of dikes. Geofabrics placed above the water level would require UV stabilization. We understand that ACZ Marine in The Netherlands has issued some schematic drawings of underwater "geotube" placement of dredgings but it is not yet known whether there have actually been installations of these tubes.

The concept of a "geocontainer" has been developed in Europe. This consists of lining the bottom of a bottom-dump barge with geofabric, filling the barge with dredgings, sewing the fabric over the top, and then dumping the entire unit into water. We understand that the water content of dredged materials has been a problem in the use of this technique.

It is our understanding that there has not been any use of layered geofabrics for underwater dredging disposal beyond the concept of the sewn pillows. It is likely that the geofabrics would not serve an extensive function in containing the migration of contaminants out of contaminated dredgings, although some types of geofabrics may have an affinity for some contaminants by adsorption.

If a geofabric were to be used, it is likely that a polyester would be necessary, since its specific gravity is about 1.36. The specific gravity of polypropylene is less than 1, and it would obviously have the tendency to float.

E. CAPPING CONTAMINATED DREDGINGS

The environmental impact of dredgings disposed of in open-water depends on the amount and type of contaminants present, and the mobility of these contaminants by biological or hydrodynamic processes. Redeposition of dredgings into water may not change the dredgings chemistry significantly, as opposed to upland disposal under dry conditions. There must be control and/or treatment of contaminants for restricted open-water disposal. The objective of these controls is to place the material accurately and in a discrete area, with controlled spreading and minimal turbidty in the upper water column over the short term. Over the long term, the object of control is the stability of the material after placement.

The concept of disposing of contaminated dredgings underwater in open-water areas, is currently under study by the Corps of Engineers at the Waterways Experiment Station. The efficiency of capping contaminated sediments in-place underwater is also under study. Capping is the addition of a layer of some type of material over the mass of dredgings at the disposal site, to isolate the dredgings from the environment. The long term impacts associated with soluble diffusion, convective transport, and bioturbation are reduced when a capping control measure is used. Physical stability of the dredgings may also be increased by capping although short term instability may be a problem if the capping material is applied too rapidly over weak dredgings which have not been allowed to consolidate.

In the past, there has been a significant amount of research regarding cover materials for burial of hazardous spills in lakes and waterways and this research would also apply to capping contaminated dredged materials. The materials that can be used to cover contaminated dredged materials are in three categories: inert, chemically active, and sealing agents. Inert materials include coarse grained and fine grained soils. Research is currently underway to determine the thicknesses of inert materials required to inhibit bioturbation of contaminated material and to retard leaching of contaminants into the water column.

At the present time, field studies conducted by the Corps of Engineers have been inconclusive regarding the efficiency of capping to prevent contaminant uptake by water column and organisms. Before capping of contaminated dredgings becomes a practical alternative technology, the physical, chemical, and biological impacts of capping must be better understood. Research conducted to date has indicated that, in particular, hydrophobic organic compounds probably would eventually break through various soil capping materials. The use of geofabrics would not impede this break through.

Other capping materials which are available, chemically active and sealing agents, could neutralize or otherwise decrease the toxicity of dredgings.

Another consideration which must be addressed in the use of capping, is the stability of the cap under the hydrodynamics of the system. The cap must be protected from wave action and currents in the water, since disturbance of the cap may displace and redistribute contaminated material.

One method of disposing of contaminated dredgings underwater is called shallow-water confined (depths of about 10 to 60 feet), which would be applicable in the Deep Hole. A thicker cap is needed in this design as compared to deep-water confined disposal. The pathways of escape for contaminants are increased over deep water designs due to currents induced by convection of soluable fractions. Further, bioturbation and leaching into the underlying soils are of more concern in the shallow water environment than in deep water.

It is our opinion, based on review of available information and our experience with island construction in other settings, that the matter is technically feasible. In this report, we have discussed specific topics which must be addressed in determining the feasibility of open-water disposal of dredging spoils and the construction of islands from dredging spoils in Duluth-Superior Harbor. It would require additional study, including site specific studies of the geotechnical properties of the harbor bottom soils at the proposed island locations as well as through study of the dredgred materials to be used.

REFERENCES

1. Department of the Navy, Naval Facilities Engineering Command, Design Manual 7.2 - "Foundations and Earth Structures" (Alexandria, Virginia, 1982)

2. Department of the Navy, Naval Facilities Engineering Command, Design Manual 7.3 - "Soil Dynamic Deep Stabilization, and Special Geotechnical Construction" (Alexandria, Virginia, 1983)

3. Department of the Navy, Naval Facilities Engineering Command, Design Manual 38.2 - "Weight Handling Equipment and Service Craft" (Alexandria, Virginia, 1981)

4. Cullinane, John et al. Contaminated Dredged Material: Control, Treatment and Disposal Practices (Noyes Data Corporation, Park Ridge, New Jersey, 1990)

5. Salomon, Ward and Rorstner, U., editors. Chemistry and Biology of Solid Wastes: Dredged Material and Mine Tailings (Springer - Verlag, New York, 1988)

6. Government Accounting Office Report B-221499, "Legislation needed to extend the life of CDF" (Washington, D.C., August, 1986)

7. Personal contact with Dr. Jack Fowler, Geotechnical Engineer, Corps of Engineers Waterways Experiment Study, Geotechnical Branch (Vicksburg, Missippi)

8. Personal contact with Mr. Joel Sprague, Manager of Engineering Services, Nicolon Corporation (Norcross, Georgia)

9. Personal contact with Mr. John Jaschke, Area Hydrologist, Minnesota Department of Natural Resources (Duluth, Minnesota)

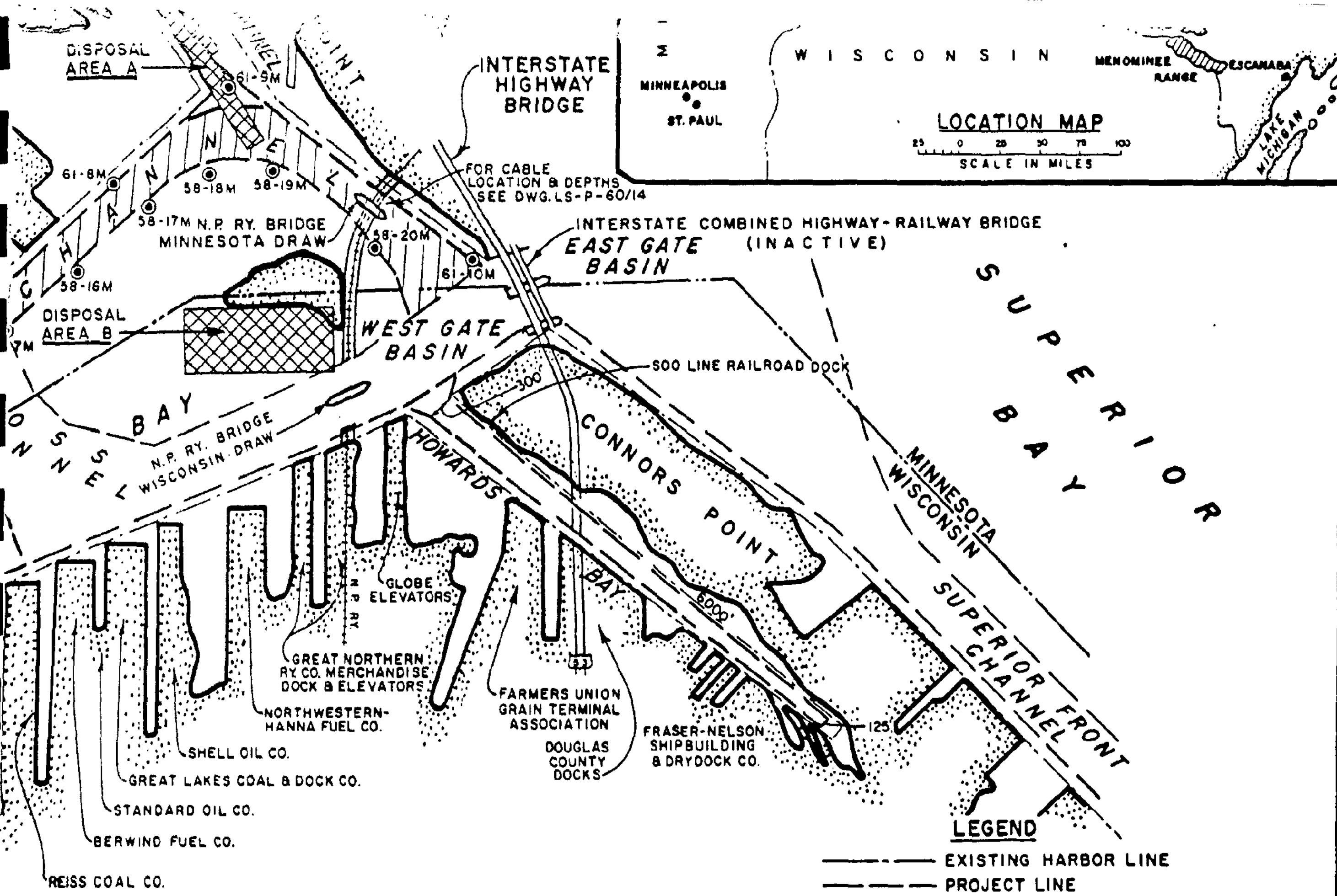
10. The Northwest Regional Planning Commission, "Superior Harbor Dredged Materials Disposal Report" (Spooner, Wisconsin, November, 1989)

11. Wang, X.Q., Thibodeaux, L.J., Valsaraj, K.T. and Reible, D.D. "Efficiency of Capping Contaminated Bed Sediments In Situ" (Environmental Science Technology, Volume 25, No. 9, 1991, pp. 1578 to 1584)

WCK:smc

Appendix E.

Boring Logs
U.S. Army Corps of Engineers



LEGEND

- EXISTING HARBOR LINE
- PROJECT LINE
- AREA TO BE DREDGED
- DISPOSAL AREA
- BORING LOCATION & NUMBER
- SUBMERGED CABLE OR PIPELINE CROSSING

or no fines

less than 50.

nit greater than 50.

on
by the letter F. Numbers to the
ne number of blows required to
split tube sampler 1 foot using
" drop.
PL (Plastic Limit) are shown
g.

NOTES:

1. PROJECT DEPTHS AND SOUNDINGS ARE REFERRED TO LWD 600 FEET ABOVE MWL AT FATHER POINT, QUEBEC (IGLD 1955) (INTERNATIONAL GREAT LAKES DATUM 1955), (LWD ELEVATION 600.0 IGLD = LWD ELEVATION 601.6 ABOVE MEAN TIDE AT NEW YORK CITY).
2. FOR TYPICAL SECTION, SEE DRAWING: LS-P-60/15.
3. FOR DISPOSAL AREA PLAN SEE DRAWING: LS-P-60/16

THIS DRAWING HAS BEEN REDUCED TO ONE-HALF THE ORIGINAL SCALE

SCALE

#10 .0737"	#40 .0165	#200 .0029"	
SAND			FINES
course	medium	fine	silt or clay

SYMBOL	DESCRIPTION	DATE	APPROVAL

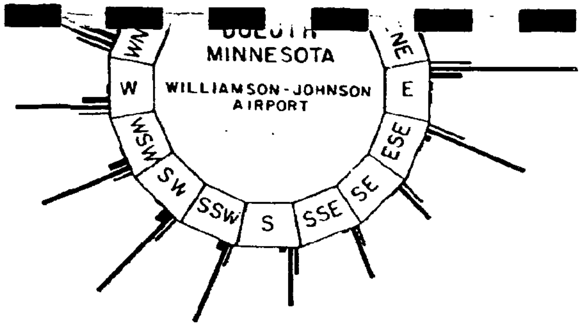
U. S. ARMY ENGINEER DISTRICT, ST. PAUL
CORPS OF ENGINEERS
ST. PAUL, MINNESOTA

DESIGNED BY: L.D.
DRAWN BY: V.T.C.
CHECKED BY: W.R.S.
SUBMITTED BY: [signature] CHIEF ... BRANCH
APPROVED: R. W. Leonard CHIEF ENGR. DIVISION
APPROVED: [signature] COL., CORPS OF ENGINEERS

LAKE SUPERIOR
DULUTH-SUPERIOR HARBOR MINNESOTA-WISCONSIN
DREDGING NORTH CHANNEL
PROJECT PLAN

DATE: MARCH 1968
SCALE: AS SHOWN
SPEC. NO. DACW 37-68-B-0044
DRAWING NUMBER LS-P-60/13
SHEET 1 OF 4

1 of 2



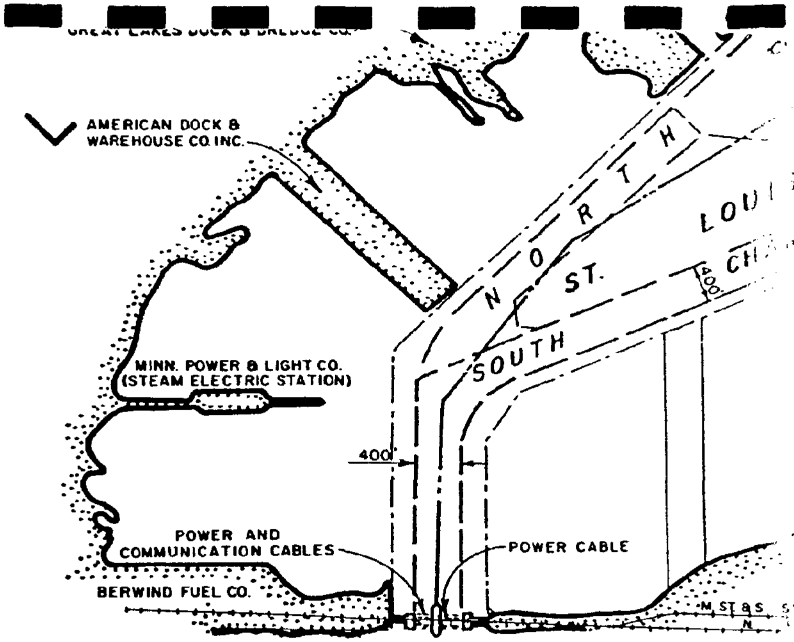
PREVAILING WINDS

THIS CHART REPRESENTS THE AVERAGE DAILY VELOCITY AND AVERAGE DURATION IN DAYS PER YEAR OF WIND FOR YEARS 1950 TO 1960 INCLUSIVE. WIDTH OF RADIATING LINES INDICATES AVERAGE DAILY VELOCITY IN M.P.H.

0 TO 7 MILES PER HOUR
8 TO 18 MILES PER HOUR
19 TO 31 MILES PER HOUR
32 TO 38 MILES PER HOUR
39 TO 46 MILES PER HOUR
47 OVER MILES PER HOUR

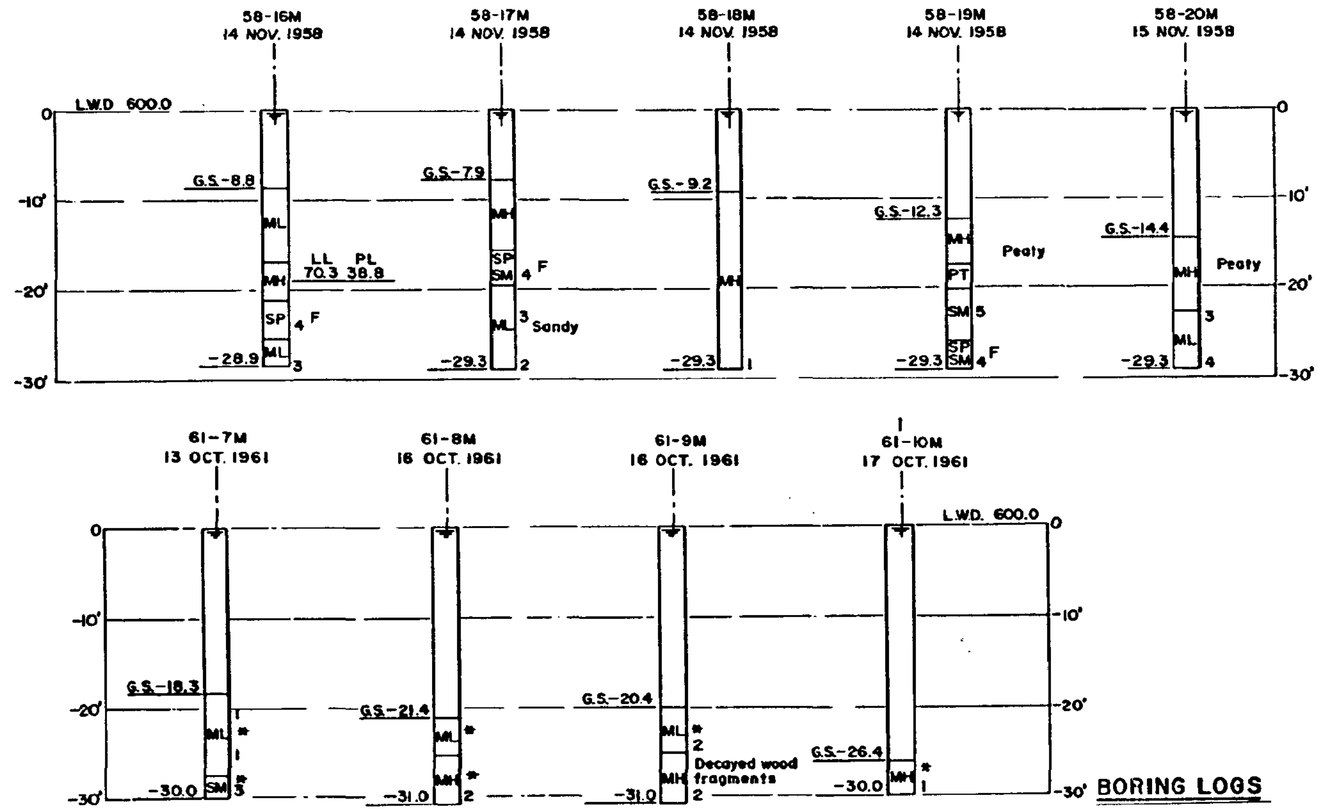
LENGTH OF RADIATING LINES INDICATES AVERAGE RECURRENCE IN DAYS PER YEAR

10 0 10 20 30 40
SCALE IN DAYS



PROJECT PLAN

1000 500 0 1000 2000
SCALE IN FEET



BORING LOGS

LEGEND

SP Poorly graded
SM Silty sands
ML Inorganic silts,
MH Inorganic silts
PT Peat
Water

Note: * = Field c
Fine sand is
right of the borin
drive a 2" I.D. anc
a 250 lb. hammer
LL (Liquid L
to the right of the

GRAI

30"	6"	2"	3/4"
BOULDERS	small boulders	cobbles	GRAVEL
			course