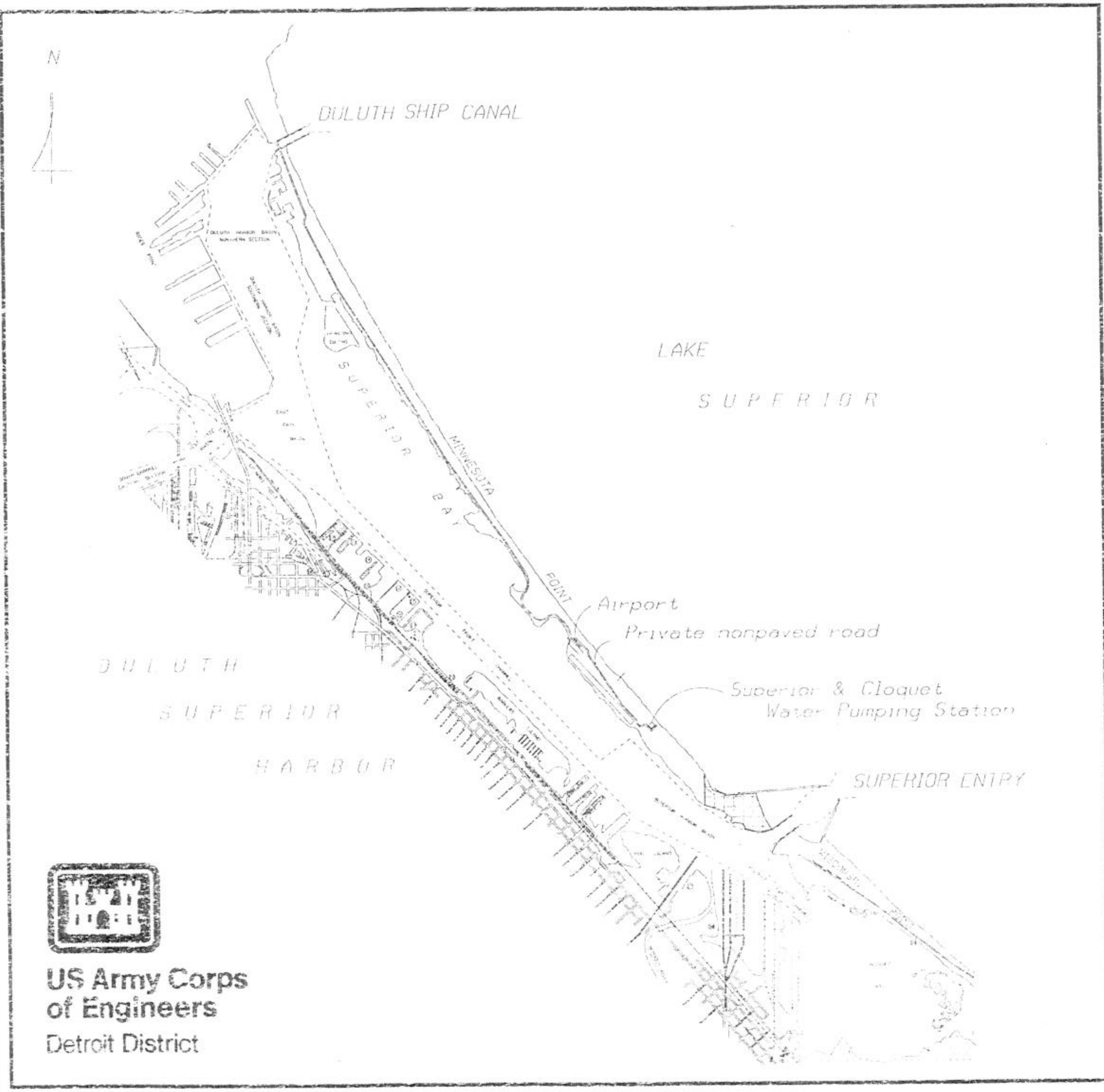
DETAILED PROJECT REPORT
SECTION 111 STUDY
MINNESOTA POINT, DULUTH, MINNESOTA

FEBRUARY 2001



US Army Corps
of Engineers
Detroit District

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1. INTRODUCTION

Minnesota Point is located about 150 miles north of Minneapolis St. Paul, Minnesota, at the extreme western end of Lake Superior in Duluth, Minnesota. Along with Wisconsin Point it makes up the largest fresh water baymouth bar in the world, and separates Duluth-Superior Harbor from the main body of the lake. Minnesota Point is that portion of the bar lying between the North Shore of Lake Superior and the Superior Bay and extends a distance of about 5.5 miles between Duluth Ship Canal and the Superior Entry to the harbor.
A map of the harbor is shown in Figure 1.

The study addresses the problem of shoreline erosion along Minnesota Point resulting from the interruption of alongshore littoral transport processes at Duluth Entry and Superior Entry. The entire reach of Minnesota Point between Duluth Entry and Superior Entry is adversely affected; however, the prime areas of concern are along two reaches, each several hundred yards long, located to the east of the Duluth Entry and to the west of Superior Entry (See Figure 2). Therefore, these areas will be the focus of the investigation. Prior erosion studies include the 1974 Section 111 Detailed Project Report (DPR) Beach Erosion Control on Minnesota Point at Duluth, Minnesota published by the St. Paul District. Their conclusion was a no action alternative.

The piers forming the Duluth and Superior Entries to Duluth-Superior Harbor jointly have the potential to effect beach erosion patterns on the shoreline of Minnesota Point. At this time the only erosion that has been observed has been along two short stretches of beach - one located adjacent to, and south of the Duluth Ship Canal, and the other adjacent to, and northwest of, the Superior Entry. The latter is uninhabited, except for a pumping station and the end portion of a small airport runway. Along the 3,000-foot stretch of beach adjacent to, and southeast of, the Duluth Ship Canal, about five blocks of residential property on the lake side of Minnesota Point appear to be threatened. About 33 residential buildings and an equal number of garages and sheds are involved. The beach, between the property line and the shoreline, is publicly owned.

A reconnaissance of the area was made by representatives of the Coastal Engineering, Detroit District Office personnel to investigate existing and historical conditions. To assist the Corps in their investigation W.F. Baird & Associates, LTD, of Madison, Wisconsin, was commissioned to study the coastal engineering aspects of the site. Their results are incorporated into this report.

2. PURPOSE

The purpose of this study is to identify adverse impacts from the Federal navigation structures at Duluth-Superior Harbor to the shoreline of Minnesota Point, and to develop plans to mitigate shore damages attributable to those structures. The study area includes the Lake Superior shoreline along Minnesota Point, beginning at the Duluth Ship Canal and extending a distance of about 5.5 miles south, to the Superior Entry (which forms the natural breakwater for the harbor). See map of study area shown in Figure 2.

3. AUTHORITY

This detailed project report was prepared under the authority of Section 111, River and Harbor Act of 1968 (PL 86-645) as amended (Mitigation of shoreline erosion damage caused by Federal navigation projects). This investigation was formally requested by Mayor Gary Doty of Duluth, Minnesota in a letter dated December 12, 1996.

4. LAKE SUPERIOR

Lake Superior has a surface area of about 31,700 square miles and drains a land area of about 49,300 square miles. It is not only the largest of the Great Lakes, but is also the deepest, the maximum recorded depth being 1,333 feet. Low water datum for Lake Superior, an arbitrary plane to which elevations of the lake surface are referred, is 600.0 feet above mean water level as measured at Father Point, Quebec, (International Great Lakes Datum, 1955). Water from Lake Superior discharges through the St. Marys River for a distance of about 60 miles into Lake Huron. To compensate for the effects of power diversions around St. Marys Rapids in the vicinity of Sault Ste. Marie, a gated dam was constructed across the St. Marys River at the head of the rapids. Since the completion of this dam in 1921, the-discharge from Lake Superior has been completely controlled under the supervision of the International Joint Commission through its International Lake Superior Board of Control.

5. TOPOGRAPHY

Minnesota Point is a low natural sand bar about 6 miles long which varies in width from about 300 to 1,400 feet. It is cut by the Duluth Ship Canal about 3,000 feet southeast of the North Shore, and is separated from Wisconsin Point and the South Shore by the Superior Entry to Duluth-Superior Harbor. On the lake side of this bar, between the two harbor entrances, is a flat sand beach. Dune formations exist in the backshore areas beginning about 3,000 feet southeast of the Duluth Ship Canal and ranging in elevation from 10 to 25 feet above low water datum. Northwest of the Duluth Ship Canal the beach is composed of gravel with some sand and is fairly steep. The backshore area has been filled and leveled to accommodate both public and private developments, and ranges in elevation from 6 to 10 feet above low water datum. Southeast of the Superior Entry on Wisconsin Point, the lake side beach is similar to the beach found on the southeastern portion of Minnesota Point. Dunes in the backshore have elevations which range between 10 and 15 feet.

The harbor side of Minnesota Point has been built up over the years with deposits of dredge material. These deposits have become vegetated but remain relatively low. Backshore elevations vary from 6 to 8 feet and there are no dune formations.

Minnesota Point is about 600 acres in size or approximately 1 square mile. Land developed for residential purposes accounts for 37 percent of the total area and is located in the northwestern half of the point. Industrial development is limited to the most northerly end of the point. Also located on Minnesota Point are two churches, nine recreation areas, a school, and a small private airport. The southerly third of the area is generally undeveloped except for the airport, the Park Point Recreation Area and a water intake facility owned and operated by the Superior Water and Light Company. Almost the entire lakeside beach of the point, including the area subject to erosion, is open to the public. Most of the residential neighborhood is located within one block of this open space area.

6. HISTORY AND DESCRIPTION OF FEDERAL NAVIGATION PROJECT

Improvements for the harbors at Duluth and Superior and for their individual entries were considered separately until the projects were consolidated by the River and Harbor Act of 3 June 1896. The original Federal project was begun at Superior under the authorization of the River and Harbor Act of March 1867. The project at Duluth had an unusual start. The Northern Pacific Railroad Company began construction of a rock-filled timber crib breakwater, parallel to and about 1,400 feet northeast of Minnesota Point. The breakwater had reached a length of approximately 400 feet 'when the 1871 River and Harbor Act provided for the Federal Government to finance a 2,622-foot extension to the railroad breakwater. The justification for this action was to provide a harbor area in Lake Superior for the city of Duluth. At approximately this same time, the city was constructing a dock, referred to as the citizen's dock, parallel to the then nonexistent Duluth Canal. In April 1871, the city of Duluth and the Northern Pacific Railroad Company opened a canal through Minnesota Point at the existing canal site. In 1872, the breakwater, after reaching a length of approximately 1,000 feet, was destroyed by a severe storm. The River and Harbor Act of 1873 provided for abandoning any further work on the breakwater and instead provided for preserving and improving the Duluth Canal. The citizens dock and the breakwater were then left to the elements. The two harbor projects at Duluth and Superior were subsequently modified by the River and Harbor Acts of 1873, 1883, 1884, 1886, 1888 and 1892. The two harbors were consolidated and considered as one by the River and Harbor Act of 3 June 1896.

6.1 SUPERIOR ENTRY

The River and Harbor Act of 1867 initiated improvement of the Superior Entry, and was the beginning of Federal involvement in the development of the Duluth-Superior Harbor. The entry was to be located at what was thought to be the natural outlet to the lake from Superior Bay. General opinion and some evidence at that time indicated that the natural outlet actually migrated and a more stable entry could be developed through Minnesota Point farther to the northwest. The final plan, however, was for the construction of two piers to stabilize the existing outlet. The piers were to consist of rock-filled timber cribs, capped by a continuous superstructure of the same material, placed 350 feet apart, and were to extend to the 18-foot depth in the lake. The piers, when actually constructed, attained a greater length than planned, due to the tendency of shoals to develop in front of the entry. This was caused by littoral drift from the south shore and Wisconsin Point. When completed in 1874, the Wisconsin Pier was 2,856 feet long, the Minnesota Pier was 2,656 feet long, and the channel depth between the piers was 12 feet. In 1878, 200 feet of shore protection was, placed near the Minnesota Pier to retard erosion which was feared could breach the landward end of the pier. By 1894 the combined lengths of the two piers had reached 5,650 feet. The depth in the channel was being maintained at 17 feet, and the adequacy of the structure to withstand future deepening was in question.

The River and Harbor Act of 3 June 1896 called for replacement of the piers of the Superior Entry. However, the piers were strengthened with vertical timbers and the foundations with riprap. Then, in 1900, work commenced on a new concrete superstructure. However, by 1901, a 24-foot depth was being maintained in the channel, which placed the crib bottoms above the bottom of the channel. Considerable displacement of the piers was reported, and replacement was recommended. Major reconstruction of the entry was begun in 1903 under a plan for building two new concrete revetment piers. The construction of the Wisconsin Pier was initiated in 1903, and work was suspended pending a modification of the plan. Amended in 1907, the project provided for building a new Minnesota Pier and, removing the two old rock-filled timber crib piers; the formation of a wave stilling basin by building converging breakwaters in the lake; and for dredging the basin and entrance channel.

The Wisconsin Pier built in 1903 and 1904 is 1,600 feet long and the Minnesota Pier, built during the period 1907 to 1909, is 2,096 feet long. These piers are 500 feet apart with a channel depth of 27 feet maintained between them. The arrowhead breakwaters were built between 1909 and 1914. The northerly one is 4,667 feet long and, the other is 1,866 feet long, with an opening between them of 600 feet.

6.2. DULUTH SHIP CANAL

In 1871 and 1872, appropriations provided by the River and Harbor Act of 1871 were applied to the extension of a breakwater northeast of Minnesota Point. This breakwater projecting from the north shore was started by the Northern Pacific Railroad to protect their docks on the lakeshore because there was no entrance into Superior Bay at Duluth. During the same time period the Duluth Ship Canal was dug by the Northern Pacific Railroad and the city of Duluth. Construction of the canal was begun against the advice of the Corps of Engineers. However, with the completion of the canal, a harbor in the lake at Duluth was not needed. The River and Harbor Act of 1873 provided for the United States to accept the responsibility for maintenance and improvement of the canal. Federal improvement of the canal was completed in 1881, and consisted of two parallel rockfilled timber crib piers, each 1,200 feet long, projecting 600 feet into the lake, and a canal 150 feet wide and 16 feet deep. In 1888, the U.S. Government accepted formal transfer of the canal and adjacent property, but the transfer was not completed until 1894 due to the difficulty in determining ownership of some of the property.

The River and Harbor Act of 1896 called for the rebuilding of the entrance as the canal was considered too shallow and narrow for vessel safety. The piers were in disrepair and the foundation had been weakened by scour. The new piers, which are those for the present canal, were constructed from 1898 to 1900 in general accordance with the 1897 plan of improvement. They are each 1,700 foot long timber cribs with concrete superstructures, and project 1,150 feet from the shoreline. The clear width between the piers at the entrance and for a distance of 1,250 feet from the lakeward end is 290 feet, after which they flare out at the harbor 'end to a width of 540 feet. The least depth of the channel midwav between the piers was 26 feet. Over the years (1985 to present) changes to the Duluth Ship Cannel have included, (1) added toe protection for the piers, (2) SSP with concrete walkways and walls and (3) project depths of 32 feet for the approach channel and 28 feet for the canal.

7. SITE CONDITIONS AND COASTAL PROCESSES

W.F. Baird & Associates, LTD, of Madison, Wisconsin, was commissioned to study the coastal engineering aspects of the site. For details of the site conditions and coastal processes see Appendix A, Hydraulic & Hydrology Analysis. The following paragraphs provide a brief summary of items that characterize the coastal processes along Minnesota Point.

(a) Waves. One aspect of the investigation was a wave analysis. A wave analysis was conducted to determine the open water fetches on Lake Superior over which winds can generate waves. Minnesota Point shoreline is clearly exposed to very long fetches towards the east and east-northeast. Therefore, while prevailing winds may be from the westerly sectors, the largest wave events are associated with easterly and northeasterly wind conditions.

(b) Wind. Another aspect of the investigation was the wind. Winds were obtained from a local station and used as input to the coastal processes numerical model. Thirty years of wind data (1961 to 1990) was extracted for the Duluth International Airport. Of all the tests, the prediction of alongshore transport with waves generated from the Baird model with Duluth International Airport winds as input data resulted in the highest net northward transport rate.

(c) Lake levels. During the course of each year the water surface elevation of Lake Superior is subject to a consistent seasonal rise and fall, reaching its lowest stage usually at about the close of winter and attaining its highest stage during the late summer. The water levels on Lake Superior fluctuate within an average annual range of about 0.3 m with highs in mid to later summer and lows early spring. Due to the shape of the western arm of Lake Superior it is likely that the study shoreline experiences considerable wind generated storm surges during severe events, possibly in the range of 0.6 to 1 m in height above the average lake level. Low water datum (LWD) on Lake Superior is 183.2 m above IGLD85.

(d) Ice. Although ice usually begins to form in early December it has little effect on the lake side of Minnesota Point. Within the harbor the expansive pressure of the ice sheet can cause damage to shore structures, and abrasion during the spring breakup can damage both artificial and natural shore protection. However, the lakeward beaches of the point are, if anything, protected by the ice from winter storm waves. These waves tend to force the ice sheet toward the shore. The lakeward edge of the sheet is then broken off by wave action and thrown onto the ice sheet. The ice sheet reforms at its edge and the process is repeated. This action produces large mounds of ice just offshore. Later, during the spring thaw, these mounds of ice melt slowly and act as breakwaters during spring storms. As a result, most wave damage on Minnesota Point occurs in the fall.

(e) Geomorphology. Geomorphology is defined as the science dealing with the nature and origin of the earth's topographic features. Minnesota Point is part of a 10 km (6 mile) long sand and gravel barrier between the Duluth-Superior harbor and the main body of the Lake. The plan width of the Point ranges from 90 to 425 m (300 to 1,400 ft). The feature is considered to have originated (Ref 1) from sand transported by the St. Louis and Nemadji Rivers and stabilized by the littoral drift from the adjacent Wisconsin and Minnesota shores

In previous studies, two areas of erosion concern have been identified (Ref 1).

The first location is immediately south of the Duluth Entry, for a length of approximately 915 m (3000 ft). The landward area of this reach is developed and comprises residences and related structures. A previous report (Ref 1) notes that damage to the residences along the shore in this area has been limited to seepage into basements due to high lake levels. Further damage results from wind blown sand, are a direct result of residential construction on an active dune system. Through the remainder of this report this zone of concern will be referred to as Area 1 (see Figure 3 at the end of the main report).

South of the Duluth Entry (including Area 1) the major nourishment schemes that were carried out in the 1930s and again in 1963 resulted in a flatter shoreline according to Ref 1. In fact, at the time of the Section 111 Report (Ref 1) the opinion of the Corps was that beach slopes near the Duluth entry area of concern (Area 1) were very flat, as much as 1 on 80, and the future shoreline was predicted to have a stable plan shape lakeward of the 1873 position. From examination of the most recent navigation chart (NOAA Chart 14975 -- which is based on 1981-2 NOS surveys in along the Point), the shoreline at that time was 40 to 50 m (131.2 to 164 ft) lakeward of the 1873 shoreline position. A comparison of a digital air photo taken on 17 May 1991 to the Chart 14975 shoreline (representing a 1981/2 position) shows little or no change in the shoreline position in Area 1 (see air photo on Figure 5 at the end of the main report). Therefore, it is likely that the present shoreline is located lakeward of the 1873 shoreline position.

The second location of erosion concern is located northwest of the Superior Entry, an area which is largely undeveloped and where the political urgency for remedial action is not as great. This area of erosion concern will be referred to as Area 2 throughout the remainder of this report (see Figure 4 at the end of the main report).

Shoreline erosion on the northwest side of Superior Entry was recognized previously (Ref 1). From comparison with historic bathymetry data sets, it would appear that the shoreline has not stabilized and further erosion is expected. (See Figure 6 at the end of the main report)

From the analysis in Appendix A, it can be concluded that the area of concern relating to beach erosion is focussed primarily in the reach northwest of the Superior entry (Area 2) for a length of about 1,500 to 2,000 m (5,000 to 6,500 ft).

(f) Alongshore Transport Rates. The movement of sand by wave action (and currents generated by waves) is the primary driving force for erosion and deposition along sandy shores. Transport of sand by wind can be an important factor but is generally secondary in comparison to quantities of sand transported by waves. Erosion and deposition of sand and the resulting shoreline change is a result of gradients in actual rates of alongshore and cross-shore transport. For this investigation the COSMOS numerical model has been applied to predict the alongshore transport. See Appendix A, Section 3.4 for a detailed analysis.

At all locations the northerly directed transport rate dominates the southerly directed component (refer to Appendix A, Table 3.4a). Generally, northerly transport is in the range of 55,000 to 60,000 m^3/year (71,934.5 to 78,474 cubic yards/year) and southerly transport is approximately 9,000 m^3/year (11,771.1 cubic yards/year). Predicted transport rates on either side of the Superior Entry are very similar. There is a slight gradient of diminishing net northerly transport rate moving from southeast to northwest along Minnesota Point corresponding to the slow change in shoreline orientation. Predicted bypassing potential at both Entries is low enough to be considered insignificant.

Therefore, because of the cut off of sand supply from the south results in a situation where the beach is evolving towards a stable orientation to the waves, ongoing shoreline change (and the associated erosion and deposition) can be expected in the future. As this is a long term process, the future rate of erosion will be similar to that experienced in the past 100 years.

(h) Cross-Shore Transport and Profile Response. In contrast to the long term shoreline changes associated with gradients in alongshore transport, cross-shore transport gradients result in short term erosion of the beach and dune areas during storms, particularly those that occur during high lake level conditions. During these storm events, sand is eroded from the beach and dune and deposited in the form of bar deposits in the nearshore zone. At Minnesota Point, storm events which cause erosion typically occur during the spring and fall (the shore is almost always protected by ice in the winter months). Subsequent to erosion events, and usually over the summer months, sand is moved back onshore during periods of less energetic wave conditions, and particularly when the lake levels are lower. Therefore, erosion related to cross-shore transport is a critical issue during high water level periods. Numerical model tests have been completed to simulate the beach and dune erosion that occurred during severe storms that were experienced between 1958 and 1987. See Appendix A for the detailed analysis.

In Area 1 south of the Duluth Entry the residences are constructed within the natural dune zone for this beach. Therefore, cross-shore related dune erosion during periods of high lake levels will be a critical concern in this area (i.e. as the dunes are eroded, wave runup and wave overwash impact the residences through flooding and physical damage).

In summary, over a 30-year period, there were 20 to 30 events when significant beach and dune erosion would be experienced in conjunction with flooding impacts to the residences along Lake Ave, which parallels the lakeshore. The beach stability is significantly improved with the presence of coarse sand from a depth of 1 m below LWD up to the dune face.

(i) Circulation Patterns. It would appear that there is a general convergence of flows in the Duluth Entry area (wave generated currents from the north and south and offshore directed flows through the channel driven by river discharge).

In Appendix A, Section 3.4 it was determined that there is a dominant northward alongshore transport direction along Minnesota Point. The alongshore transport is driven by a dominant northerly directed, wave generated longshore current. However, there will also be a southerly directed longshore current generated along the Minnesota shore at the north end of the Point. This convergence is illustrated on Figure 7 at the end of the main report. The photo used as a backdrop for Figure 7 was taken during a period of strong ENE wave attack and signs of the converging flow patterns are evident with a possible plume of offshore directed sediment laden flow located offshore of Area 1 (see Figure 7 at the end of the main report).

8.0 SEDIMENT BUDGET

A sediment budget takes the available information on sinks and sources of sediment and attempts to balance these contributing factors over a given period of time for a specific area in order to develop an understanding of the erosion and deposition processes in the area of interest. This information can then be used to project future changes with and without mitigation or intervention. For details of the sediment budget analysis see Appendix A, Hydraulic & Hydrology Analysis. The following paragraphs provide a brief summary of the results of the sediment analysis.

The sediment transport estimates outlined in Appendix A, Section 3.4 indicate that the potential net northward rate of sand transport on the northwest side of Superior Entry is 52,500 m^3/year (68,664.8 cubic yards/year). This compares well to the rate of deposition of 49,000 m^3/year (64,087.1 cubic yards/year) southeast of the Entry derived from estimates of shoreline change and lakebed change. Owing to the fact that little or no sand bypasses the Superior Entry from south to north, the resulting sand supply deficit of 52,500 m^3/year (68,664.8 cubic yards/year) is compensated by erosion from Area 2.

At the north end of the reach between the two channels, Area 1 should be a depositional zone. The net potential average alongshore transport rate at Area 1 is 45,100 m^3/year (58,986.3 cubic yards/year) to the north. Also, from the numerical model estimates of alongshore transport, it was determined that little or no sand bypasses the Duluth Entry from south to north. As discussed in Circulation Patterns, for E and ENE wave conditions the convergence of currents generated from wave action along the Minnesota shore to the north and along Minnesota Point to the south probably result in a strong offshore directed current. Therefore, the sediment budget is closed by assuming an annual offshore loss of 45,000 to 50,000 m^3/year (58,855.5 to 65,395 cubic yards/year) at the north end of Minnesota Point. Evidence from depths contours on the hydrographic charts suggest that the sediment is transported offshore into depths of 20 m (65.6 ft) or more.

9.0 CAUSES OF EROSION

This section presents a summary of the causes and nature of erosion for the two areas of concern – Area 1 located south of the Duluth Entry and Area 2 located northwest of the Superior Entry.

9.1 Erosion Area 1

Area 1 consists of a 915 m (3000 ft) long reach of shoreline located immediately south of Duluth Entry along Lake Ave (refer to Figure 3).

This area is a zone of convergence for alongshore sand transport, but importantly, it is also a zone of convergence for northwest and southeast directed lake circulation patterns (generated by ENE and E wave events) which results in a strong offshore directed rip current during these storm events. Without a detailed assessment of wave generated circulation patterns using a 2D depth-averaged numerical model of radiation stress generated currents, it is not possible to state equivocally that these offshore directed flows would have been located in the vicinity of Area 1 prior to construction of the harbor. However, it is likely that the harbor has had only a minor impact on these larger scale processes. The result of this zone of convergence is deposition of sand in deeper water offshore of the beach. This is the reason that deposition does not occur along the shoreline located south of the Duluth Entry as may be expected with net northerly sand transport.

Also, this strong offshore directed current and related sand transport pathway explains why the large beach nourishment projects of in the 1930's and again in 1963 were relatively short lived.

One impact of the harbor structure on erosion Area 1, that can only be assessed qualitatively, is the elimination of a supply of gravel to the beach. Prior to the construction of the Duluth Entry gravel transported from northeast to southwest along the Minnesota shore would have eventually reached the Area 1 shoreline. That this transport occurred in the historic past is evidenced by the presence of a considerable volume of gravel at the northwest end of Minnesota Point, however there is little evidence to indicate that significant transport is occurring along the Minnesota shore at the present time. The small amount of gravel that is transported along Minnesota shore is evidenced by the near absence of accretionary features along Minnesota Point north of Duluth Entry jetties. In addition, the absence of an accretion fillet adjacent to the north jetty suggests that, since the construction of Duluth Entry, the transport of gravel to Area 1 would not have been significant with or without the presence of the Duluth entry. Without the presence and continued supply of this material, the beach in Area 1 would become more susceptible to erosion damage during periods of high water level, however there is no evidence to indicate that, since the construction of the Duluth Entry, there is either significant transport of gravel to Minnesota Point along the Minnesota shore or that the Duluth Entry jetties block what little gravel is transported to Minnesota Point. The results of the cross-shore profile response modeling showed that this area was susceptible to storm erosion on a relatively frequent basis. This circumstance, combined with the fact that the residences along Lake Ave have been constructed within the natural dune system, has resulted in a situation where these homes are subject to flooding from wave runup and overtopping. It is possible that the shoreline could erode to an extent where the houses would be directly damaged by erosion during severe storm events (i.e. with a return period greater than 20 to 30 years). The results of the numerical model also showed that if the dune, beach and shallow nearshore all consisted of coarse 2-mm sand, the erosion potential would be significantly reduced. It is unlikely that the beach consisted entirely of coarse sand and gravel prior to the construction of the Duluth Entry. However, even the presence of patches of sand and gravel (which is more likely to have been the pre-development beach condition) would have some mitigating influence on storm erosion potential.

Relative crustal rebound has been mentioned as a concern regarding the long-term erosion potential along the Point. In Area 1, an increase in the lake level relative to the landmass would increase the frequency of overtopping events and the related erosion and flooding.

In summary, the erosion problem in Area 1 is related to temporary erosion during storm events. The problem is primarily related to the position of the residences relative to the active dune system. The creation of the Duluth Entry has created a potential barrier to along shore transport. There is evidence to indicate that Duluth Entry has disrupted transport of sand being transported from south to north past the jetties, however there is no evidence to indicate that jetties have interrupted the transport of gravel from the north to Area 1. However, even with the presence of gravel on the shore, the area behind the dunes would remain susceptible to flooding from overtopping events – this is a natural process on this type of dune/beach feature.

9.2 Erosion Area 2

Area 2 consists of a 1500 m (5000 ft) long reach of shoreline located immediately northwest of the Superior Entry (refer to Figure 4). Features within area 2 include the following; the Superior & Cloquet Water Pumping stations, an old pine stand and the Sky Harbor Airport.

The cause of erosion in this area is straightforward. The construction of the Superior Entry has resulted in the near total elimination of sand supply to Minnesota Point on the northwest side of the Entry. Almost 100% of the sand supplied by the eroding shore is either deposited in the 2 km long fillet beach updrift (and southeast) of the Entry or it is deposited in deeper water via an offshore directed rip current. Therefore, Area 2 is eroded at a rate equivalent to the potential net northerly sand transport rate, which is approximately 52,500 m^3/year (68,664.8 cubic yards/year). This amounts to an average shoreline recession rate in this area of 1 to 2 m/year (between 1914 and 1981/2, refer to Figure 6).

The stable shoreline orientation associated with zero net transport to the north was determined to 83° which is 26° off the existing average shoreline azimuth along Minnesota Point (see Figure 8 at the end of the main report). It is noted that due to the accuracy of the wave hindcast, wave transformation and sediment transport prediction procedures it cannot be stated that the stable orientation is exactly 83°. However, and importantly, it is certain that the stable orientation is significantly different that the existing shoreline orientation of Minnesota Point. With the complete cut off of sediment supply from the south (i.e. by the presence of the Superior Entry) the shoreline orientation is no longer in equilibrium and will slowly change until it reaches the stable orientation associated with zero net transport (providing the supply is not reinstated through beach nourishment or bypassing measures). Therefore, the erosion along Area 2 will continue unabated at a relatively uniform rate in the future as the shoreline slowly evolves towards the stable orientation shown in Figure 8.

It is important to note that prior to the creation of the Duluth and Superior Entries the only natural outlet for the bay existed near the location of the Superior Entry. The natural channel is reported to have been approximately 460 m (1500 ft) in width and 1.2 to 5 m (4 to 16 ft) deep. While this channel would have impeded the northerly directed sand transport to some degree; it is reasonable to assume that the present condition with a 10-m deep navigation channel is responsible for nearly all of the erosion presently occurring northwest of the Entry.

A rise in the lake level relative to the land mass driven by crustal rebound would not influence the primary driving force of erosion in Area 2, that is the deficit of alongshore sand supply. However, a relative rise in lake level could increase the chance of a breach in conjunction with the existing erosion pressures in Area 2.

In summary, the erosion in Area 2 will continue unabated in the foreseeable future as the shoreline orientation adjusts to a situation of no net supply. As a result, a breach in the beach on the northwest side of Superior Entry is a very real possibility in the future. Other potential impacts in Area 2 include; the Superior & Cloquet Water Pumping stations, an old pine stand and the Sky Harbor Airport.

10. EROSION MITIGATION ALTERNATIVES

The objective of any erosion protection measures that might be implemented in Area 1 would be to protect the shore from the temporary erosion and flooding that occurs in conjunction with storms at high water levels. Since it was determined that Area 1 is not a Federal Responsibility, alternatives 1 and 2 discussed below are for information purposes only.

The objective of any erosion protection measures that might be implemented in Area 2 would be to address the annual deficit in sand supply. Any attempt to address this erosion problem with a structural solution will simply shift the problem to the northwest. Therefore, if a structural option (e.g. submerged breakwaters) were implemented it would eventually lead to structural protection being implemented for the entire length of Minnesota Point.

10.1 Alternative 1 – Coarse Beach Fill, Erosion Area 1

This alternative consists of placing clean coarse dredged material from Duluth-Superior Harbor onto Area 1, which includes a 915 m (3000 ft) long reach of shoreline located immediately southeast of the Duluth Canal. By using coarse material it will reduce the rate of spreading and thus, replacement frequency. It will require approximately 18,300 cubic meters (23,934.6 cy) of material ranging from sand to gravel to small stone, replaced every 10 years. It is important to note that the coarse sand beachfill would not alleviate the flooding issues, as the beach/dune crest elevation would not be increased with this alternative. Also beachfill will eventually spread to the south depositing gravel over the sandy recreational beaches.

10.2 Alternative 2 – Fine Beach Fill, Erosion Area 1

This alternative consists of placing clean fine dredged material from Duluth-Superior Harbor onto Area 1, which includes a 915 m (3000 ft) long reach of shoreline located immediately southeast of the Duluth Canal. It will require approximately 1,000,000 cubic meters (1,307,900 cy) of "natural" fine sand, replaced every 5 years. Maintains existing fine to medium sand beach. This alternative simulates pre-harbor conditions to some extent but sand supply is more intermittent.

10.3 Alternative 3 – Coarse Beach Fill, Erosion Area 2

This alternative consists of placing clean coarse dredged material from Duluth-Superior Harbor onto Area 2, which includes a 1500 m (5000 ft) long reach of shoreline located immediately northwest of the Superior Entry. By using coarse material it will reduce the rate of spreading and thus, replacement frequency. It will require approximately 75,000 cubic meters (98,092.5 cy) of material ranging from sand to gravel to small stone, replaced every 10 years. The advantage is as gravel spreads northward it offers natural protection to a greater length of shore. Gravel component is not lost offshore and will eventually serve as protection to areas further to the north, including Area 1.

10.4 Alternative 4 – Fine Beach Fill, Erosion Area 2

This alternative consists of placing clean fine dredged material from Duluth-Superior Harbor onto Area 2, which includes a 1500 m (5000 ft) long reach of shoreline located immediately northwest of the Superior Entry. It will require approximately 300,000 cubic meters (392,370 cy) of "natural" fine sand, replaced every 5 years. Maintains existing fine to medium sand beach. This alternative simulates pre-harbor conditions to some extent but sand supply is more intermittent.

10.5 Alternative 5 – Portable Bypassing Plant Erosion Area 2

This alternative consists of installing a portable, bypassing plant on the south side of Superior Entry and pump clean dredged material to the north side of Superior Entry to supplement Area 2. It will require approximately 60,000 cubic meters (78,474 cy) of "natural" fine sand, annually. Maintains existing fine to medium sand beach. Since the material to be bypassed would be obtained from the Wisconsin side of the Superior Entry, it would necessitate a cooperative agreement among the Corps of Engineers and the states of Minnesota and Wisconsin. It is unknown whether or not the state of Wisconsin would be agreeable to removing sand from this area. This proposal makes use of sand that is being deposited updrift of the harbor. Also note that by using the portable bypass plant, it will reduce dredging requirements for Superior Entry Channel. This alternative best simulates natural conditions prior to harbor construction with constant bypassing.

10.6 Alternative 6 – Close Superior Entry

This alternative consists of closing the Superior Entry to allow existing beach sand to transport naturally alongshore. The exiting channel breakwaters, would be removed, Superior Entry would be de-authorized and shipping would be rerouted though the Duluth Channel.

10.7 Alternative 7 – Off shore Submerged Breakwater

This alternative consists of constructing a continuous submerged offshore breakwater between Duluth Canal and Superior Entry, which would dissipate wave energy of incoming waves prior to the waves reaching the beach. Ice-conditions would tend to favor rubblemound structures as opposed to steel sheet piling, because of ease of repair and maintenance. With this type of breakwater, erosion would continue until the area between the structure and the shore built up to a stable bottom profile and a protective beach formed. Eventual prevention of damage would result. Submerged breakwaters are a navigational hazard to small craft and would require warning equipment. Breakwaters projecting out of the water may completely halt most waves, but they are expensive to construct and are aesthetically displeasing.

10.8 Alternative 8 – No Action

A recommendation that no action be taken to alleviate or mitigate the beach erosion would not burden the taxpayer with the financial costs associated with the other alternatives. However, the do nothing option will eventually threaten the Superior and Cloquet pumping stations, the historic lighthouse, an old stand pine trees and will lead to a breach between the lake and the bay.

11. EVALUATION OF EROSION MITIGATION ALTERNATIVES

11.1 Alternative 1 – Coarse Beach Fill, Erosion Area 1

This alternative will require approximately 18,300 m^3 (23,934.6 cubic yards) of material ranging from sand to gravel to small stone, replaced every 10 years. It is unlikely that the required volume of the necessary sized material could be obtained from maintenance dredging alone. It is likely that a portion of this material would have to be obtained from onland sources. This material could be obtained from a commercial source and transported to the erosion zone by truck or boat. Placement of the material could be by direct application to the affected area or by stockpiling along the shore and having the material distributed by shore currents. Wave action would sort, adjust slopes, and dissipate the material. Placement of the coarse material would be more costly, but it would be more acceptable to the general public and aesthetically more appealing. The natural beach material for the erosion area is the gravel and cobbles of the north shore, and it is against this material that the coarse purchased material would have to be compared. Unlike the dredge material, little problem with wind blown sand would exist. As discussed in Section 9.1, Erosion Area 1 above, it has been determined that the erosion in Area 1 is related to temporary erosion during storm events and not caused from the Duluth Canal, therefore the placement of the coarse material would be a non-Federal responsibility.

11.2 Alternative 2 – Fine Beach Fill, Erosion Area 1

Potential erosion damages could be greatly reduced through such measures as the continued deposition of maintenance dredging material when available. Under this scenario, beach nourishment will require approximately 1,000,000 m^3 (1,307,900 cubic yards) of "natural" fine sand, replaced every 5 years. It is likely that most of this material could be supplemented from upland sources. The disadvantage is that the fine sand is affected by wind and wave action, which eventually is lost offshore. As discussed in Section 9.1, Erosion Area 1 above, it has been determined that the erosion in Area 1 is related to temporary erosion during storm events and not caused from the Duluth Canal, therefore the placement of the fine material would be a non-Federal responsibility.

11.3 Alternative 3 – Coarse Beach Fill, Erosion Area 2

This alternative will require approximately 75,000 cubic meters (98,092 cy) of material ranging from sand to gravel to small stone, replaced every 10 years. It is unlikely that the required volume of the necessary sized material could be obtained from maintenance dredging alone. It is likely that a portion of this material would have to be obtained from onland sources. This material could be obtained from a commercial source and transported to the erosion zone by truck or boat. Placement of the material could be by direct application to the affected area or by stockpiling along the shore and having the material distributed by shore currents. Wave action would sort, adjust slopes, and dissipate the material. The natural beach material for the erosion area is the gravel and cobbles of the north shore, and it is against this material that the coarse purchased material would have to be compared. Unlike the fine material, little problem with wind blown sand would exist. This type of material, however, is less desirable for a recreational beach than the finer grained dredge material. This alternative will distribute the erosion problem further to the north. Since Area 2 is being impacted by a Federal Navigation structure, it will be carried forward for further consideration.

11.4 Alternative 4 – Fine Beach Fill, Erosion Area 2

Potential erosion damages could be greatly reduced through such measures as the continued deposition of unpolluted dredge material when available. Under this scenario, beach nourishment will require approximately 300,000 m^3 (392,370 cubic yards) of "natural" fine sand, replaced every 5 years. It is likely that most of this material would be obtained from onland sources. The disadvantage is that the fine sand is affected by wind and wave action, which eventually is lost offshore. Since Area 2 is being impacted by a government structure, it will be carried forward for further consideration

11.5 Alternative 5 – Portable Bypassing Plant Erosion Area 2

It is highly unlikely that the State of Wisconsin would be agreeable to removing sand from the southern side of Superior Entry. A cost estimate was developed using data from a similar project developed by the U.S. Army Corps of Engineers Waterways Experiment Station for Semi-Fixed Bypassing Plant, titled, "Shinnecock Inlet, New York, Site Investigation, Report 2, Evaluation of Sand Bypasing Options; Technical Report CHL-98-32 (Dec. 1998). In comparing the life cycle costs on Table 2, this alternative is not the least costly. Considering the unlikely ability to obtain an agreement from the State of Wisconsin to remove sand from Wisconsin point, this alternative is no longer being considered.

11.6 Alternative 6 – Close Superior Entry

If the Superior Entry were closed, then the only shipping channel available would be the Duluth Canal. The Duluth Canal has a lift bridge over it and if the lift bridge was damaged, then all inbound and outbound shipping within Duluth-Superior Harbor would stop.

In 1997 upwards of 13,000,000 tons of taconite traversed the Superior Entry, originating at the Burlington Northern-SF ore docks in Superior, WI. The ships, which carry this product, are primarily 1,000-footers which carry upwards of 60,000 tons per trip. This amounts to over 400 trips through the Superior Entry each year. Due to the water depths between the ore docks and the deep water of Lake Superior, ships are able to load to 28 feet, a deeper draft then the project depth of 27 feet. If the Superior Entry were impassible for whatever reason, ship traffic would have to traverse the Superior Front Channel which also has a project of 27 feet and exit by the Duluth Ship Cannel. Controlling depths in the Superior Front Channel do not exceed 27 feet. This would add an additional 15 miles per round trip, adding a minimum of three hours per round trip. In addition a ship would load to a draft of one foot less to traverse the Superior Front Channel. An inch of draft for a 1000-footer amounts to approximately 220 tons of taconite. A foot of draft amounts to 2,640 tons of taconite. Combining time and cargo capacity lost, not being able to use Superior Entry would have a significant impact on transportation costs from the Burlington Northern-SF ore docks. It is highly unlikely that the State of Wisconsin or the shipping industry would agree to closing Superior Entry. In comparing the life cycle costs on Table 2, this alternative is not the least costly solution. Considering the potential impacts to the shipping industry and the fact that this alternative is not the least costly, this alternative is eliminated from further consideration.

11.7 Alternative 7 – Off shore Submerged breakwater

This alternative has been studied previously under the "Section 111 Detailed Project Report, Beach Erosion control on Minnesota Point at Duluth, Minnesota, U.S. Army Corps of Engineers, St. Paul District, November 1974". The report proposed constructing a detached submerged rubble mound breakwater, initiating at the Duluth Canal and extending 3,200 feet south. According to the current Hydraulic & Hydrology Analysis any structural solution must consider the entire shoreline or the erosion problem will shift, therefore the proposed submerged breakwater would need to be 5.5 miles long. The total cost for the detached submerged rubblemound breakwater is $26,989,000. In comparing life cycle costs in Table 2, this alternative is not the least costly, therefore this alternative is eliminated for further consideration.

11.8 Alternative 8 – No Action

If Area 2 continues to erode, a breach may occur between the lake and the bay, the impacts to the inner Duluth-Superior Harbor would be significant. Without the sand bar to protect businesses located along the inner harbor, wave action or ice forces have the potential to cause severe damage. Also, if erosion reaches the Superior and Cloquet pumping stations and causes damage, the community could lose a valuable water supply.

	Table 1 Cost Summary of Alternatives						
	Alternative	Quantity	Units	Unit Price	Estimate	Contingencies	Total Cost
1	Coarse Beach Fill Area 1 (Ten year cycle)	23,934.6 (18,300 M^3)	CY	19.22	$ 460,000	$ 115,000	$ 575,000
2	Fine Beach Fill Area 1 (Five year cycle)	1,307,900 (1,000,000 M^3)	CY	11.78	$ 15,406,000	$ 3,852,000	$ 19,258,000
3	Coarse Beach Fill Area 2 (Ten year cycle)	98,092.5 (75,000 M^3)	CY	21.65	$ 2,124,000	$ 531,000	$ 2,655,000
4	Fine Beach Fill Area 2 (Five year cycle)	392,370 (300,000 M^3)	CY	9.93	$ 3,898,000	$ 974,000	$ 4,872,000
5	(Annually) Portable Bypassing Plant	78,474 (60,000 M^3)	CY	5.58	$ 438,000	$ 109,000	$ 547,000
6	Close Superior Entry	1	LS	7,236,000	$ 7,236,000	$ 1,809,000	$ 9,045,000
7	Offshore submerged breakwater	1	LS	21,591,000	$ 21,591,000	$ 5,398,000	$ 26,989,000

Note: Unit price for beach nourishment between Area 1 and Area 2 varies due to the difference in the haul distance and placement difficulty.

	Table 2 Life Cycle Comparison				
	Alternative	Cycle	First Cost 1999 Dollars Present Worth	Replacement over 50 year life cycle	Total cost over 50 years
1	Coarse Beach Fill Area 1	Ten year cycle	$ 575,000	5	$ 2,875,000
2	Fine Beach Fill Area 1	Five year cycle	$19,258,000	10	$ 192,580,000
3	Coarse Beach Fill Area 2	Ten year cycle	$ 2,655,000	5	$ 13,275,000
4	Fine Beach Fill Area 2	Five year cycle	$ 4,872,000	10	$ 48,720,000
5	(Portable Bypassing Plant Annually)	Annually	$ 547,000	50	$ 27,350,000
6	Close Superior Entry	50 year cycle	$ 9,045,000	1	$ 9,045,000
7	Offshore submerged breakwater	50 year cycle	$26,989,000	1	$ 26,989,000

12. ECONOMIC ANALYSIS

The authority of this study is to reduce or eliminate damages induced by the existence of the Federal project. Section 111 authority provides for a justified level of damage reduction. W.F. Baird & Associates identified only one area (Area 2) as impacted by the project. The economic analysis focuses on Area 2.

The period of analysis is 50 years. The analysis uses the Federal discount rate, i.e. 6 5/8%, for Fiscal Year 2000. The value of one dollar, 50 years in the future, is 4 cents today. The alternatives are assumed to be implemented in the year 2001.

The Corps considers the harbors of Duluth and Superior one facility. In 1997, shipments to and from the harbor totaled 41.9 million short tons. The primary commodities are iron ore (18.5 million tons) and coal (14.7 million tons). Other significant commodities include grain (3.4 million tons) and limestone (3.3 million tons).

The Superior entrance provides the most direct route to two major facilities, the Burlington Northern iron ore dock and a grain elevator.

In Area 2, the study identified five main direct impacts of potential economic concern:

- An old growth pine stand threatened from shoreline retreat,
- The Superior & Cloquet Water Pumping Stations,
- The possibility of a breach occurring northeast of the Superior entry due to lack of adequate sediment supply,
- Sky Harbor Airport runway would eventually be threatened, and
- Minnesota Point Lighthouse.

12.1 Land

The pine stand comprises most of the northern two-thirds (1000m) of Area 2. The water pumping stations and the service road to them roughly divided the pine stand in half. South of the pumping station, the pine stand varies in depth from about 100m to 350m. North of the pumping station the pine stand depth varies from about 50 m to 100m. The total area is about 16 hectares or 40 acres. The owner recently donated 17.6 acres of this through the Minnesota Land Trust to the Minnesota DNR. This includes about half of the shoreline in Area 2. The property was appraised in 1999 at about $650,000 as part of the donation process. The Minnesota DNR plans to use the property as a scientific and natural area. The average value is about $37,000 per acre.

The Corps of Engineers also contracted for an independent appraisal of the land value as part of the study of potential construction easements. This value, $115,453 per acre is used in the economic analysis to compute benefits from preventing erosion.

12.2 Improvements

The water pumping stations are located approximately 53.3 m (175 feet) from the eastern shoreline and 27 m (89 feet) from the bluff line. These pumping stations deliver water to Superior, WI and Cloquet, MN. The City of Cloquet owns the larger facility, which has 3 pumps and a large wet well. The primary user is Potlatch Paper Corp., a paperboard products firm in Cloquet, which uses about 8 to 14 million gallons a day. Superior Water Power and Light owns the smaller facility and distributes about 4 million gallons a day to residents and businesses. Superior Water Power and Light plans to replace and relocate their facility closer to the shoreline so that it is adjacent to the Coquet facility. One owner provided an estimated value for their facility. Based on that information, we assume the total value of both facilities to be $10 million.

The Minnesota Point Lighthouse stood 50 feet in height when completed in 1858. The lighthouse is now essentially a historically significant ruin. The house was moved and the tower abandoned over a century ago, in 1878. Two-thirds of the lighthouse tower stands at a height of 35 feet. An important aspect of the ruin is that it marks the "zero" point for all of the original mapping surveys of Lake Superior.

The study did not obtain specific information about the terminals that a breach might affect and Sky Harbor Airport.

12.3 Without Project Condition

Currently, much of the material dredged from near the Superior entrance is barged to the Erie Pier CDF for disposal. The remaining material is deposited on either Minnesota Point or on Wisconsin Point beaches.

If erosion occurs at a rate of 2.2 m/yr. along the entire 1,500m stretch of Area 2, the total area expected to erode each year is 0.8 acres. Most of this, 0.4 acres, would be pine forest. The annual value of pine forest lost would be about $15,000. Assuming the remaining land to be valued at the same highest and best use, the total value of land lost to erosion would be about $94,000.

The pump houses would be damaged in 9 years without protection. Undermining of the pump house is unlikely to occur. It is more reasonable to assume that, without a project, the plants would be relocated before a more costly catastrophe, i.e. no water, occurs. The plants are assumed to be moved in 8 years, before the bluff line reaches the pump house without the project.

Other loses are expected to occur outside the 50 year planning horizon of this study. Unless it is cost effective to prevent losses anticipated to occur in the next 50 years, it is better to save costs and the interest on those costs until a point in time when these loses are more eminent. With a dollar 50 years in the future worth 4 cents today, the decision to protect Area 2 should not be based on protecting improvements that will not be threatened for decades.

Immediately inside the harbor, beyond Minnesota Point, there are the two marine terminals mentioned above and one non-maritime industry according to the Metropolitan Interstate Committee's 1989 land use map. Exposure to direct wave action would be unacceptable. However, a breach through Minnesota Point is not expected to occur within the next 50 years. This concern should not affect the decision to prevent erosion for many decades to come.

Sky Harbor Airport is located in the center of Minnesota Point. Runway 32 extends about 300 meters into Area 2. The runway is over 100 meters inland from Lake Superior. Although it is subject to the threat of erosion, given the annual erosion rate of about 2m, it would not be threatened within the 50 year planning horizon of this study. This concern should not affect the current decision to prevent erosion .

The Minnesota Point Lighthouse is located about 100 meters inland from Lake Superior. It also would not be threatened within the 50 year planning horizon of this study.

12.4 With Project Alternatives

Benefits

All of the alternatives protecting Area 2 are assumed to prevent all future erosion. The equivalent annual value of this protection is about $508,600. The estimated benefits shown in Table 3 below are limited to Area 2. The annual benefits of preventing erosion are the same - $508,590 - for all alternatives protecting Area 2.

TABLE 3
EROSION DAMAGES
SUPERIOR ENTRANCE

Improvements	
Value	$ 10,000,000
Period (yrs)	8
Present Value (6 5/8%)	$ 5,985,875
Annual Value (50 yrs)	$ 414,444
Land	
Value per acre	$ 115,453
Acres lost per year	0.82
Annual Value of Erosion	$ 94,146
Total Annual Damages	$ 508,590

Coarse Beach Fill: This alternative involves trucking and placing gravel on the beach. The only vehicle access to Minnesota Point is over the Duluth channel lift bridge. The bridge has a total weight limit of 35 tons for multi-axle vehicles. Each cy of material weighs about 1.5 tons. It would require over 3,000 truckloads to deliver 98,093 cy of sand every 10 years. The gravel will spread northward and offer protection to a greater length of shore than just Area 2. However, the gravel will change the nature of the beach.

Fine Beach Fill: This alternatives maintains the natural sand beach, but relies on trucks instead of nature to place the material. It would require over 8,000 truckloads to deliver 242,370 cy of sand every 5 years.

Sand Bypass: The sand bypass will likely reduce the amount of deposition in the Superior Entry Channel. The Superior Entry was dredged in 1990 and 1998. Assuming these years represent a typical dredging cycle, the annual sedimentation rate in the entrance channel is about 5,600 cy. Assuming the bypass would prevent about 50% of that sedimentation, the sand bypass would save the cost to dredge about 2,800 cy annually. The annual savings at $5 per cubic yard would be about $14,000.

Close Superior Entry: The existing piers, constructed in 1909 now need significant repair. The concrete is deteriorating from the inside. A cost estimate for repairs is not available. However, the District awarded a $2.5 million contract in June 1998 for repair of about a 500-ft. section of the pier. Including engineering, design, supervision, and administration. The total cost of this ongoing repair may be at least $10 million.

The total length of the piers is about 3,700-ft. The remaining 3,200-ft. of pier is expected to need repairs at a lower average unit cost than the 500-ft length already under repair. Assuming that unit cost to repair the remaining pier is only about 60% ($3,600) of the unit cost of ongoing repairs, the remaining repairs will cost an estimated $10 million.

The cost to remove the piers is expected to be $9 million. About $4 million of this cost is for trucking and disposal of the rock and concrete as waste. This analysis assumes that the rock and concrete cannot be recycled and must be disposed of in a landfill. Otherwise, the net up front cost of removing the pier might be significantly reduced. Also, significant portions of the piers might be left in place without disrupting sand movement, or if removed, they may provide environmental restoration benefits not included in this analysis.

It would cost less to remove the piers than to repair them. The future cost of dredging and pier maintenance would also be saved. Dredging cost $28,000 on an annual basis. No value is placed on the savings from maintaining the piers or breakwaters. This undetermined value may well exceed $100,000 a year, but would require additional effort to estimate, especially since the piers are undergoing a major rehabilitation. Future maintenance costs for the piers, after the rehabilitation is complete, should be lower than recent history would indicate.

The entrance channel does serve a purpose. It allows ready access to the port facilities on the South side of Duluth Superior Harbor. In calendar year 1997, 1,087 inbound and 1,179 outbound cargo vessels used the two entrances. That totals 2266 vessel transits. The majority of these transits occur at the Duluth entrance. About 500 commercial cargo vessels transit the Superior channel each year. Most are ore vessels using the Burlington Northern docks. Vessels using grain elevators also use the Superior Entrance Channel.

The Superior channel is located about six miles from the Duluth entrance. The terminals accessed through the Superior entrance are located near the Superior entrance channel. Closing the Superior channel would add about 5 miles and one hour for each one way transit.

About half of the vessels transiting the Superior channel are the largest vessels navigating the Great Lakes, 1,000-footers. The average cost of operating these vessels is about $800 per hour. The cost of replacing the average capacity, overhead, and administration costs would be about $700 per hour for a total cost of $1,500 per hour. Closing the Superior entrance would add about $300,000 to the annual cost for Class 10 vessels. Class 7 vessels shipping grain and iron comprise most of the remaining shipping. Their operating costs are about $600 per hour and we assume the other costs are about $550 per hour for a total cost of $1,150 per hour. Closing the Superior entrance would add about $230,000 to the annual cost for Class 7 vessels. Total added annual cost is estimated to be $530,000.

The lift bridge over the Duluth entrance channel is due for extensive repairs in the year 2000. These repairs will involve closing the Duluth channel. This project would not be implemented before then. The possibility of future short-term and long-term closures of the Duluth entrance channel should be considered in any future study.

Without the piers, the entry channel would silt up to some degree. However it is a natural outlet for the St. Louis and Nemadji Rivers. As first charted in 1861, the natural channel was 1,500 ft wide and varied from 4 to 6 ft deep. The channel could be used for recreational boats with little or no future maintenance.

Offshore Breakwater: This alternative costs over $25 million and is not carried forward for further study because of it's relatively high cost. In addition, the vast majority of benefits would likely accrue to areas not covered by this authority.

Costs

Table 4 summaries project costs. The First Cost column shows alternatives from Table 1. The next column, O&M Savings, displays such costs that would be incurred without a project with the same return cycle. These represent costs savings from terminating major repairs of the Superior entrance pier. The Shipping Cost column displays the net additional annual costs to ship ore and grain, if Superior entrance is closed.

TABLE 4 NED COSTS MINNESOTA POINT ($1000)									
						Annual			
	Area	Cycle (yr.)	First Cost	O&M Savings	Net First Cost	First Cost	O&M	Shipping Cost	Total Cost
Coarse Beach Fill	1	10	575	0	575	75	0	0	75
Fine Beach Fill	1	5	19,258	0	19,258	4,361	0	0	4,361
Coarse Beach Fill	2	10	2,655	0	2,655	348	0	0	348
Fine Beach Fill	2	5	4,872	0	4,872	1,103	0	0	1,103
Portable Bypassing Plant	2	1	547	0	547	547	14	0	561
Close Superior Entry	2	50	5,000	10,000	0	0	28	530	558
Offshore Breakwater	1&2	50	26,989	0	26,989	1,748	0	0	1,748

Notes: O&M costs in column 5 are those costs otherwise expected to be incurred with the same frequency as the cycle in column 3. Costs for Area 1 are for informational purposes.

Comparison of Alternatives

Table 5 below compares the benefits and costs of alternatives in Area 2. According to the analysis, only Coarse Beach Fill is economically justified. Fine Beach Fill is clearly not economically justified. The other two alternatives are marginally close to being economically justified. It is possible that further study might determine that one or both of these alternatives would cost less or be more beneficial than estimated. However, the relatively low cost of Coarse Beach Fill clearly makes it the plan that will maximize net benefits.

TABLE 5 COMPARISION OF ALTERNATIVES SUPERIOR ENTRANCE ($1000)				
	Benefits	Costs	Net Benefits	B/C
Coarse Beach Fill	509	348	160.19	1.5
Fine Beach Fill	509	1,103	(594.65)	0.5
Portable Bypassing Plant	509	561	(52.47)	0.9
Close Superior Entry	509	558	(49.53)	0.9

13. REAL ESTATE REQUIREMENTS

13.1 General

Review of project drawings revealed that there are no structures or improvements in the project study area, which need to be removed. There will be no impact on commercial and industrial properties as a part of the project. There is no known federally owned land within the proposed project area. There are no cemeteries in the project area. The area is serviced by utilities, however, the project will not require the removal nor relocation of these utilities. For details of the Real Estate Plan see Appendix D.

14. ENVIRONMENAL REQUIREMENTS

An Environmental Assessment (EA), pursuant to the National Environmental Policy Act (NEPA), addressing beach nourishment at Minnesota Point using dredged material or material from other sources was mailed out to the public and coordinated with interested agencies in September 1998. A Finding of No Significant Impact (FONSI) and a 401 water quality certification, or waiver thereof, would be required from the state of Minnesota.

The final array of considered alternatives were assessed to the level of detail and information available. The EA provides detailed discussion of the potential environmental impacts (human environmental, natural environment, and cultural resources) of the proposed action. The conclusion of the environmental assessment indicates that no significant cumulative or long-term adverse environmental effects would be expected as a result beach nourishment at Minnesota Point.

15. COST SHARING AND FINANCING

15.1 Feasibility Study Costs

The local project sponsor is responsible for 50 percent of the feasibility study costs for costs exceeding $100,000. Feasibility study costs under $100,000 are 100 percent Federal responsibility. The cost of this Feasibility study is $100,000, therefore Non-Federal funds are not required for this Feasibility phase.

15.2 Implementation Costs

Implementation consists of the preparation of Plans and Specifications, real estate acquisitions, construction, and, supervision and administration. Implementation costs will be shared using the same procedure and provisions used for projects which are specifically authorized by Congress. Local interests shall agree to assume responsibility for designated items of local cooperation and for all projects cost in excess of the specified Corps cost limitations. Cost for preparation of Plans and Specifications will be initially Federally financed and later recovered from the sponsor during project construction as part of the total project (implementation) cost.

The River and Harbor Act of 1867 initiated improvement of the Superior Entry, and was the beginning of Federal involvement in the development of the Duluth-Superior Harbor. The initial construction of Superior Entry was prior to the establishment of a local cooperation agreement. The first congressionally authorized local cooperation agreement for Duluth Superior Harbor wasn't established until 1952. The initial local cooperation agreement is shown in the document, *REPORT UPON THE IMPROVMENT OF RIVERS AND HARBORS IN THE DULUTH, MINN., DISTRICT, DEPARTMENT OF THE ARMY, OFFICE OF THE CHIEF OF ENGINEERS, 1954, page 1036.* The initial local cooperation agreement states, "Public Law 568, July 16, 1952, provides that local interests shall give assurances satisfactory to the Secretary of the Army that they will provide without cost to the United States all necessary lands, easements, rights-of way for the initial construction, and for subsequent maintenance when and as required; and hold and save the United States free from damages due to the construction and maintenance of the project. Negotiations with local interests are in progress. There are no prior requirements of local cooperation." With respect to implementation costs and cost sharing provisions authorized by Congress when the harbor was established, and since there was no cost sharing agreement when the harbor was initially authorized in 1867, the implementation funding will be at 100% Federal expense.

15.3 Mitigation of Shore Damage

Mitigation of Shore Damage is defined as the implementation of structural or non-structural measures to reduce erosion-type damages by shoreline stabilization. The target degree of mitigation is the reduction of erosion or accretion to the level, which would have existed without the influence of navigation works, at the time such navigation works were excepted as a Federal responsibility. However, when it is determined that shore damage to a portion of a congressionally authorized shore protection project is attributable to the navigation project, mitigation measures may be accomplished under the Section 111 authority, only to the extent of damages that can be directly identified and attributed to the navigation project.

With regard to Area 1, as a result of the Hydraulic & Hydrology Analysis (See Appendix A for details), it was determined that the percentage of total erosion damage attributable to the Duluth Canal navigation project is 0.0%. Therefore, implementation costs with regard to any mitigation measures taken for Area 1 will be funded at 100% non-Federal expense.

With regard to Area 2, as a result of the Hydraulic & Hydrology Analysis (See Appendix A for details), it was determined that the percentage of total erosion damage attributable to the Superior Entry navigation project is 100%. Therefore, implementation costs with regard to any mitigation measures taken for Area 2 will be funded at 100% Federal expense.

16. SUMMARY AND CONCLUSIONS

The evaluation of the alternatives was made on the basis of their respective costs, the damages preventable, and the social and environmental factors involved. Under the Section 111 authority, in order to provide for mitigation measures for shore damage there are two critical items, (1) it must be shown that the Federal navigation structure is contributing to the erosion problem, and (2) the damages incurred must be economically justified.

A brief summary of the hydraulic analysis and economic analysis are discussed below. For a detailed summary of the hydraulic analysis and economic analysis, see Appendix A, Section 7 *SUMMARY* and the main report, Section 12 *ECONOMIC ANALYSIS*, respectively.

Area 1

The concern in Area 1 relates to temporary flood and erosion damages to residences along the east side of Lake Ave during severe storm events. There is no long term erosion of the shoreline at this location. The primary cause of the storm related flooding and erosion problem is the proximity of the homes to the natural dune system. Overwash and overtopping of dune features is a natural process. Relative lake level rise due to crustal rebound will increase the frequency of storm related erosion and flooding in the future. The presence of the harbor entrance channel may have a secondary impact on erosion potential (but not on flooding) related to the cut off of any supply of gravel to the shoreline (i.e. from the north).

No economic analysis was conducted for area 1 since it was determined from the hydraulic analysis that the erosion in Area 1 is not due to the Federal navigation structure.

Area 2

The primary cause of erosion in Area 2 is the Federal navigational structure at Superior Entry. The harbor structures have eliminated the historic supply of sand from the southeast to the Minnesota Point shore. Due to the elimination of the historic supply, the Minnesota Point shoreline is now evolving towards a new equilibrium orientation that is considerably different from the existing orientation. Therefore, the influence of the harbor will continue to cause erosion in Area 2 and the affected area will also continue to expand further to the north in the future. The possibility of a breach will be increased by relative lake level rise related to crustal rebound. Although a natural outlet to the lake existed at the approximate location of the Superior Entry historically, the erosion related to the natural channel would have been insignificant in comparison to the present problem. In contrast, the gravel and coarse sand fractions of a coarse beachfill would remain on the beach permanently, possibly resulting in a diminishing requirement for beachfill in the future.

The economic analysis compared the benefits of the land to the costs of the various mitigation alternatives. The results of the economic analysis (page 23,Table 5) show that **Alternative 3 – Coarse Beach Fill, Erosion Area 2,** has a 1.5 B/C ratio, therefore Area 2 is economically justified. However, since the total cost of beach nourishment over a 50 year period is $13,275,000 it exceeds the per project limit, and therefore will require specific congressional authorization.

In summary it is determined that Area 2 meets the criteria for recommendation for mitigation through hydraulic analysis and economic justification and the selected plan for Area 2 is coarse beach fill.

17. RECOMMENDATIONS

"This recommendation contained herein reflects the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherit in the formulation of a National civil works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendation may be modified before they are transmitted to congress as proposal for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsor, the States and interested Federal agencies, other parties will be advised of any modification and will be afforded an opportunity to comment further."

Accordingly, because the hydraulic analysis concluded that the erosion along Area 1 is not caused by the Federal navigation structure a no action plan is recommended for Area 1. However, it is recommended that the Corps continue to use Area 1 for placement of maintenance dredging as material is available and is economically justifiable to use.

It is recommended that this project be authorized for mitigation of shoreline damages attributable to Superior Entry Federal navigation works at Duluth-Superior Harbor, MN/WI to provide shoreline nourishment areas as a means of improvement as described in this report. The estimated cost for beach nourishment per ten year cycle to the Unites States is $2,655,000 for a total project cost of $13,275,000 over a 50 year period, above the present maintenance costs. Accordingly, since the total cost of beach nourishment over a 50 year period is $13,275,000, which exceeds the per project limit, it is my recommendation that specific congressional authorization is necessary to complete the project. Following congressional authorization, funds in the amount of $ 80,000 will be requested to initiate and complete Plans and Specifications.

RICHARD J. POLO
LTC, EN
Commanding