Presque Isle Park Erosion Study
City of Marquette, Michigan

Final Report

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Coastal Dynamics, Inc
7488 Bently Lake Road
Pinckney, Michigan 48169
Phone: 734-878-0633
Fax: 734-878-2399
e-mail: gmeadows@engin.umich.edu

Institute for Wetland and Coastal Trainings and Research, Inc.
4245 Beeman Road
Williamston, Michigan 48895
Phone: 517-655-9754
Fax: 517-655-9754
e-mail: TomBennett@WetlandCoastalRes.com

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PROJECT SUMMARY

The goal of this study is to provide environmentally sound long-term solutions to the erosion concerns south of Sunset Point in Presque Isle Park, Marquette, MI (Figure 1). This multitask effort involved a comprehensive analysis of the environmental factors affecting this reach of shoreline and efforts were directed toward determining the best scenario for the preservation of the park amenities with minimal influence on the surrounding shoreline. Because of the importance of this natural and cultural resource to people of the City of Marquette, every effort was made to illicit input from local public sources and to communicate findings through public interaction.

Initially, all available historical data related to the region were obtained and reviewed. This data included historical photos of the study site and a review of historical hydrographic survey data, and environmental data such as sedimentology, wind, waves, ice formation and thickness and water levels.

An on-site investigation of Presque Isle Park was conducted including a detailed bluff, shoreline and offshore bathymetric analysis through the use of precision nearshore hydrographic surveys and conventional land survey techniques. A wind and wave climatology, including winter ice cover conditions, was developed to provide wind and deep water wave characteristics for the area.

The wave climatology and bathymetric surveys were necessary input information for the execution of a numerical model of nearshore hydrodynamics and sediment dynamics. Models of this type integrate inputs of deep water wave characteristics, water levels, shoreline morphology, sedimentology and nearshore bathymetry to estimate nearshore wave conditions and resultant long-term shoreline change, delineating the locations of wave-induced erosion in the region. Historical data is utilized to calibrate the model and to assure reliable predictions.

The modeling capability derived herein aided in the development of environmentally sound coastal engineering recommendations for the remediation of the erosion in the spirit of maintaining the natural beauty of this valuable natural resource and cultural asset. Proposed remediation options include three mitigation options, including a no action alternative. The final recommendation is based on a cost-benefit analysis of the proposed options, including analysis of construction costs, if any, and long term environmental impacts to adjacent regions. Funding options are discussed and related conceptual engineering drawings rendered.

BACKGROUND AND PROBLEM DEFINITION

In 1886, The City of Marquette obtained Presque Isle from the federal government for the purpose of a city park. Since its acquisition, the City of Marquette has been devoted to the preservation of this rare natural landscape with a minimum of artificiality. As such, the majority of the amenities (roads, picnic areas, buildings, etc…) were placed along the perimeter with less obtrusive access to the interior of the park by way of paths (Presque Isle Advisory Committee, 1997). A single one-lane road, Peter White Drive, extends around the outer rim of Presque Isle. It has been the management philosophy of Presque Isle Park to focus erosion control on those areas in which the primary cause of erosion is anthropogenic. However, recent environmentally induced erosion south of Sunset Point has placed Peter White Drive in danger of closure and possible loss. It was the purpose of this research activity to examine the causes and extent of erosion of this region of Presque Isle Park and explore possible methods of remediation.

PROJECT OBJECTIVES

The overall goal of this project was to evaluate the present and projected physical state of the site and provide environmentally sound, viable, long term and cost effective means to address the

wave erosion issue endangering the roadway south of Sunset Point. To meet this goal the following objectives were accomplished:

1. A review of all historical data in existence for the Presque Isle Park region, including bathymetric data, historical air photos, sedimentology, wind and wave data, water levels and ice formation, thickness and duration.

2. An on-site investigation that entailed detailed bathymetric analysis of the nearshore, beach and bluff region through precision nearshore hydrographic surveys and conventional land survey techniques.

3. An evaluation of current nearshore sedimentology.

4. A numerical model analysis of the shallow water wave conditions and resultant shoreline change, calibrated with historical and current data collected as part of tasks 1 through 3.

5. The development and evaluation of three mitigation options, including a no action alternative with cost/benefit analyses, recommendations, funding options and related drawings.

It is the purpose of this report to summarize these findings.

WIND AND WAVE CLIMATOLOGY

In order to accurately characterize the physical environment of the nearshore region and provide deep-water wave information for exercising numerical models, an accurate deep water wave climatology of the region was developed. The US Army Corps of Engineers Coastal Engineering Research Center Wave Information Study (WIS) for the Great Lakes provides tabular summaries of wave statistics for 84 sites in Lake Superior (Driver, et al., 1992). These tabular summaries represent the most complete statistical wave information for the site. The data is based on a 32-year hindcast of wave conditions derived from wind data collected at 8 sites around Lake Superior and input into the DWAVE numerical wave model. The annual WIS statistics provide insight into the mean wave height and period, maximum wave height and percent frequency of occurrence of waves from each of 16 compass points.

Figure 2 present a graphic representation of the WIS summary statistics for station S46, located at 46.80°N, 87.50°W. The overall mean deep water significant wave height for this location is 3.28 ft with a maximum hindcast wave of 32.8 ft. This wave occurred on November 28, 1966 at noon and approached from the north. In general, the most severe waves approach this site from the north. The mean wave period is about 4 seconds and the most common directions of wave propagation are from the north and northwest.

Based on this information, and confirmed by observation, any material which is eroded from the west shore of Presque Isle and is of a size available for transport by longshore drift, moves south towards the beach in Middle Bay.

In addition to wave hindcast information, as provided by the Wave Information Study, the National Data Buoy Center (NDBC) also maintains in-situ wind and wave observation stations in Lake Superior. These stations have been in operation through the navigation season since 1987 and provide a network of actual observations of Lake surface conditions for use in a study of this type. These data have been compiled in both time-series and as summaries of climatological conditions. In contrast to the WIS statistics, these data are broken down by month, rather than direction, and provide a summary of the monthly variation in the wave field.

NDBC buoy station 45004 is located approximately 200 nautical miles northeast of Hancock, Michigan at 47.56°N, 86.55°W. This station consists of a 3-meter discus buoy which records environmental conditions on an hourly basis. The NDBC has constructed monthly wave statistics based on measurements made between April 1980 and November 1993, 67909 records. Figures 3a and b provide the monthly and annual significant wave height, maximum wave height, mean wave period and maximum wave period.

In general, this deep water site is subject to its largest waves during the fall months with the peak in mean significant wave height during November, December and January. The calmest months are the summer months. These trends are echoed in the wave period statistics. This is important in the determination of the factors which influence erosion along an ice-influenced coast. The presence of ice during the winter months can serve to protect the shoreline from direct wave attack, but can also subject the shoreline to the erosive mechanics of ice push.

WATER LEVELS AND STORM SURGE

Also important to the evaluation of historical shoreline recession and modeling efforts is data pertaining to historical water levels. Although Lake Superior is currently under moderate water level control through the locks at the St. Mary's River, there remain some natural fluctuations to the water levels which are the result of climatological variables and seasonal changes. As water levels change, the position at which wave energy is expended in the nearshore zone and the position of the interface between land and sea shift. The latter of these two variables is evident in aerial photography and can lead to misinterpretation of shoreline recession data if not properly accounted for. Figure 4 presents the mean Lake Superior water levels for the period of record January 1918 through June 1998. This eighty year records shows the variability in Lake Superior water levels on annual and decadal time scales. The water level tends to increase from April through July due to the snow melt and increased runoff associated with the warming months. The annual low water levels prevail during the February and March when freezing temperatures lock precipitation over the basin into snowcover.

In addition to long term (annual and longer) changes in water levels, the water in the Great Lakes also responds to wind and wave set up. The US Army Corps of Engineers publishes a storm induced water level rise probability scale. The monthly rises are based on an analysis of the maximum monthly annual water level above the monthly mean for each year, as measured by a water level gauge. These values do not represent actual events of any particular storm, but

provide a relative estimate of storm induced water level changes. The statistics for Marquette are shown graphically in Figure 5. The probability of exceedance is the likelihood that the associated value of storm induced water level rise will be exceeded. For example, during July, there is a twenty percent likelihood that a storm will cause an increase in the mean water level of 1.0 foot or greater. In this particular climatology, the highest expected water level rises occur during the month of June.

WINTER ICE CLIMATE

As with any Great Lake, the presence of lake ice during a significant portion of the year impacts the environmental conditions of the lake and its surroundings. The presence of ice can serve to directly and indirectly impact sediment transport by both armoring the shoreline and covering the open lake waters. During a normal Great Lakes winter, the ice cover on Lake Superior can reach 75 percent during the second half of February and remain as high as 50 percent through the end of March. This reduction in open water area can significantly impact the wave activity on the lake.

A study of the influence of ice on coastal erosion in southern Lake Michigan was carried out by Barnes, et al. (1994). Their study encompassed a three year period and focused on the influence of ice on shoreface morphology, the transport of littoral sediments within ice and the formation of anchor ice. As a result of this study, they determined that coastal ice can in fact enhance erosion by shifting the region of active wave attack and entraining and transporting sediment. They found that the ice complex was capable of entraining a sediment load roughly equivalent to the average annual amount of sand eroded from the coastal bluffs. Although the Lake Michigan site hosted a different substrate, the conclusions of this study indicate that the ice does more than protect the shoreline from incident waves. In fact, it may act as an erosion agent through both thermal and mechanical deterioration.

BATHYMETRY/TOPOGRAPHY

Historical bathymetric data for the Presque Isle area exists in the form of bathymetric charts (paper and electronic) compiled and published by the National Oceanic and Atmospheric Administration. The current nautical chart for this region was revised and updated in 1994 (see Figure 1). Additional data on nearshore morphology and land elevations are available through the US Geological Survey topographic sheets. This data, although useful, is relatively sparse for use as a single source of bathymetric information for numerical model development. Thus, field bathymetric data acquisition was necessitated.

Precision hydrographic survey data was collected via a digital, computer interfaced survey system that incorporates fully integrated Differential Global Positioning System (DGPS) technology with digital, narrow beam, dual frequency sonar. The survey system components consist of an integrated digital acoustic depth sounder, plotter and 12 channel GPS receiver along with a dual beacon Differential GPS receiver providing horizontal accuracy of 6 feet and a vertical accuracy of 1.5 inches.

Nearshore bathymetric data consists of position/depth measurement pairs covering an area from the shoreline to a depth of approximately 30 feet Low Water Datum (LWD). Nine survey lines were established perpendicular to the general trend of the shoreline (Figure 6) from precisely placed onshore temporary benchmarks (TBM's). TBM's were placed at each survey line location and referenced to easily identifiable landmarks in the vicinity. Elevations were referenced to still water level for the day and time of each survey. The TBM location and all reference measurements were recorded in a field notebook for future site identification. Photographs were also taken for future reference and comparison.

The beach and nearshore portions of the survey extended through wading depths and was conducted using a Total Station, stadia rod and prism. Horizontal distance from and vertical

elevation with respect to the TBM were recorded at approximately equally spaced intervals of 10 feet across the beach and wading zone. In addition, coordinates of any beach features or significant slope breaks were obtained. From wading depth out to a depth of at least -30 ft LWD, a precision nearshore hydrographic survey was conducted. Depth and position (latitude and longitude) pairs are acquired every second and stored in data file via an IBM compatible laptop computer on the survey vessel. A 24 ft. Grady White offshore coastal survey vessel provides a stable offshore platform from which to conduct this portion of the survey. As both a backup and independent check of survey position accuracy, a buoy is placed at the offshore extent of the shore/wading depth survey. The precise position of these buoys was surveyed from shore with the Total Station as well as the boat survey system

In addition to the conventional precision nearshore hydrographic survey described above, a composite survey grid consisting of soundings obtained along several closely spaced cross-shore transects was obtained for Presque Isle. The purpose of this survey was to establish the current detailed bathymetry within the basin and provide a strong data set for development of the depth grid necessary for the computational modeling effort.

This bathymetric data served as the primary source of information for the creation of the rectilinear bathymetric grid used as input to the numerical modeling phase of this investigation. Figure 7 is a contour plot of the bathymetric grid developed herein.

SEDIMENTOLOGY/GEOLOGY

The geology along the western edge of Presque Isle Park consists of two main geologic units, the Jacobsville sandstone of Cambrian age and an underlying older unit of Serpentinized peridotite (Gair 1968). Gair estimates that the Serpentinized peridotite forms approximately 2/3 of the northern portion of the Presque Isle (Gair 1968). Site inspection of the west shore of Presque Isle conducted for this study confirmed Gair's findings. To the north, near survey station 1, the

Serpentinized peridotite extends 8ft. above the lake surface and is capped by approximately 3 feet of Jacobsville sandstone. This stratigraphy is fairly consistent, with some variation in the thickness of the two units, south to survey station 5. At survey stations 6 and 7 the Serpentinized peridotite was not observed. Instead a four-foot thick breccia unit extends from the lake surface and is capped by approximately a four-foot thick layer of Jacobsville sandstone. Stations 8 and 9 from the lake surface to top of bluff consist entirely of Jacobsville sandstone.

Of the two rock units the Serpentinized peridotite is much stronger and more erosion resistant then the Jacobsville sandstone. The sandstone is easily broken apart by hand pressure while a rock hammer was necessary to remove the Serpentinized peridotite. The sandstone showed signs of erosion from direct wave attack and ice wedging with thick layers of the sandstone unit breaking off. Erosion of the Serpentinized peridotite was much less obvious. The erosion resistance of Serpentinized peridotite is a critical component of the stability of Presque Isle because it underlies the sandstone and provides a stable nearshore profile. Without the Serpentinized peridotite the sandstone would rapidly erode.

ALTERNATE SOURCES OF EROSION

Ground water discharge from the bluff face was observed at only one location within the study area during the two site visits. The discharge was located near survey station 4 and was occurring at the interface of Serpentinized peridotite and Jacobsville sandstone, approximately 2 ft. below the top of bluff. The discharge was very small and localized and limited to one small area less then 12 inches wide. The discharge was minimal at the time with only small amount of flow. A very small amount of erosion had occurred to the bluff from the discharge but not sufficient to cause unstable conditions along the bluff.

AIR PHOTO ANALYSIS/NEARSHORE RECESSION

Aerial photographs from two separate years, 1977 and 1997 were used to calculate erosion rates within the study area. Each of the photographs was scanned at 1400 dots per inch using a high-resolution flat bed scanner. The scanned images were then imported into a software program to be rectified. For this study rectification involved taking the 1977 aerial photograph and geographically fitting it to the 1997 aerial photograph. This rectification was done using a Dell workstation with IRAS C software. The final product of the rectification process is a 1977 aerial photograph with the same scale and geographical orientation as the 1997 aerial photograph.

Once the photographs were rectified transects were placed, on the photographs, every 50 feet within the study area, along the western shoreline of Presque Isle Park, starting at survey station 1 and extending south to survey station 9 (Figure 8). A total of 53 transects were placed, with transect line 1 located near survey station 1 and transect 53 near survey station 9. At each transect the edge of active erosion was identified on both the 1977 and 1997 aerial photographs. The difference between the edge of active erosion was then measured between the photographs for each transect line, and bluff loss determined. The bluff retreat at each transect was then divided by the total time period between photographs, approximately 19 years, and an average annual erosion rate determined. Results of the erosion study are shown in Table I.

Only four of the 53 transects showed an erosion rate greater then 1 foot per year, and three of the four transects, lines 18, 21 and 24 were located at the northern half of the study area. The other transect line showing an average erosion rate greater than one foot per year, transect line 47, was located at the southern end of the study area between survey stations 8 and 9. Seventeen of the 54 transects showed no measurable erosion of the bluff, with 9 of the lines located in the central portion of the study area and five located at the far north end near survey station one. The most stable portions of the study area appear to be in the central portion, lines 27 thru 40, and

northern portion, transect lines 1 thru 8. Both of these areas showed little to no change during the period measured.

Erosion rate calculations obtained through the aerial photographic rectification analysis, though highly accurate, may not match erosion rates calculated from direct ground measurements if the time periods used to calculate averages are different or measurements are not obtained from the same location. For example, a one time loss of 10 feet could occur in a single erosional event and then remain stable for 20 years. If erosion had been monitored for only one year the resulting erosion rate would 10 feet per year, in this example. However, if the monitoring period extended for 20 years and no additional erosion had occurred the average annual erosion rate would be 0.5 ft., in this example. The use of long periods of time to calculate average erosion rates takes into account changes in the physical environment such as fluctuating water levels and wave climate as well as large erosional loses from one time events. The authors believe that in a natural system, with little human impact, long-term rates provide a good representation of erosional conditions occurring along the shoreline.

Differences in erosion rates can also occur depending on placement of transect lines used to determine erosion rates. Transect lines used in the photographic analysis were placed every 50 feet with no attempt made to place transects in areas that either appeared to be stable or eroding. Erosion measurements taken from individually selected areas may show erosion rates that are different, in the short term, from erosion rates obtained from randomly placed transects. In order to obtain erosion rates that are characteristic of the entire bluff it is best to place transects in a way that removes personal bias. Hence, the reason for placing transects every 50 ft.

Presque Isle Park Advisory Committee (PIPAC) has gathered on-site erosion measurements since November 13, 1998 thru June 16, 2000 and has graciously provided the data for use in this study. Erosion measurements were taken at 14 locations (Figure 9, Table II) within the study area. The PIPAC data shows the lowest erosion rates within the central portion of the study

area, aerial photograph transect lines 20 thru 44, and the greatest erosion rates at the northern end of the study area, aerial photograph transects lines 1 thru 13. Of the 14 measurements taken only two stations, 1 and 2, showed recession rates greater then 1 foot per year. Stations 3, 4, 5, and 6 showed recession rates of approximately 0.5 ft. per year. All other stations had substantially lower erosion rates.

Data collected from both the aerial photographic analysis and ground measurements, provided by PIPAC show greater erosion occurring within the northern half of the study area with lower rates near the central portion. The PIPAC data did not extend south beyond aerial photo transect line 46, hence no comparisons can be drawn.

As noted above one should not base average recession rates on a short period of data due to the potential for over or under estimating erosion rates. However, somewhat surprisingly, results of the aerial photo analysis compare well with erosion rates obtained from the PIPAC ground measurements. The only measurements showing a large difference are at stations 1 and 2 of the PIPAC data. The PIPAC data has calculated recession rates of 2.3 and 1.6 feet per year respectively compared to no change and approximately 0.45 ft. per year obtained from aerial photographs. This difference is likely the result of a section of bluff breaking off. If the bluff remains stable for a period of years, which appears likely from the longer term rates, the annual erosion rate will drop and be consistent with the rates obtained from the photo analysis.

NUMERICAL MODEL OF NEARSHORE PROCESSES

When deep water waves approach a coast, the waves undergo significant modifications due to the interaction of the wave motion with the nearshore bottom. Through this process the wave's height, length, phase speed and direction of travel changes. In the simplest case, as a wave approaches a straight coastline, with planar and parallel depth contours at an angle, that portion of the wave travelling in the shallowest water will move the slowest. This phenomena results in

a bending of the wave crests such that they tend to become parallel to the bottom contours and shoreline. This is known as topographic refraction. For a more complex nearshore bathymetry, through this bending of the wave crests, wave energy is concentrated over ridges and dispersed over troughs and depressions.

Wave diffraction is a phenomenon through which energy is transferred laterally along a wave crest. It is most apparent when a regular train of waves is interrupted by a surface piercing barrier, such as a breakwater, jetty, or island. If this phenomenon did not occur, there would exist a perfectly calm area in the lee of a breakwater. Through the process of diffraction, wave energy will move along a wave crest from a region of high wave energy to low wave energy thus "smoothing out" the effects of topographic refraction.

In order to determine the characteristics of the waves interacting with the nearshore region near Presque Isle Park, the Regional Coastal Processes Wave model (RCPWAVE) was exercised (Ebersole et al, 1986). The model was developed by the US Army Corps of Engineers as part of the Regional Coastal Processes Numerical Modeling System to predict coastal processes around man-made structures. This model utilizes a detailed nearshore bathymetry grid and deep water wave conditions as input. It produces a detailed wave height, number and direction grid based upon its calculation of the interaction of the incident deep water waves with the nearshore bathymetry.

In order to initiate the RCPWAVE modeling portion of this study, it was first necessary to establish the geometry and bathymetry of the study site. The coordinate system, datum, grid spacing, and nearshore bathymetry were defined based on the precision nearshore hydrographic surveys completed during the field investigation (see Figure 7). The offshore wave climatology was derived from WIS statistical summary described earlier (see Figure 2). The numerical rectilinear grid cell size was set at 50 feet in the cross-shore direction and 100 feet in the longshore direction, with an offshore normal of 328°. This grid spacing was dictated by the

necessity of fully characterizing the wave field with at least 3 data points per wavelength for the shortest analyzed wave The model input is limited to wave approach directions less than 67.5° off normal. The results of this analysis are shown in Figure 10 and 11.

Figure 10 presents the relative wave energies at each location within the bathymetric grid. Wave energy is that quantity which best represents the amount of energy which is available for erosive results at that location, and is proportional to the wave height squared. Each wave height field, resulting from the WIS annual mean incident wave from each direction was squared, multiplied by its individual percent frequency of occurrence and summed to form the data field displayed in Figure 10. Therefore, this figure represents the relative wave energy throughout the area due to the long term mean annual wave field. This figure shows that the highest wave energies occur near survey sites 2 through 5, with the maximum occuring on the shelf offshore of sites 4 and 5. The high energies just east of survey site 1 are not likely since there is a small island offshore of this site which the model did not take into consideration and which would serve to protect this region from the more severe mean incident waves from the north. If Figure 10 is compared with Figure 7 it is evident that the offshore bathymetry serves to control the concentration of wave energies at the northwest corner of the island. Recall that topographic highs tend to concentrate wave energy while topographic lows disperse wave energy. There is a topographic depression offshore of survey site 3 which influences the lower wave energies seen at this shore location.

Figure 11 shows the wave height field as a result of the most severe hindcast storm wave for this station, a 32.8 foot high wave with a period of 12 seconds from the north. This wave breaks in deep water and reforms several times before actually breaking upon the shore. The break depth shown by this analysis is about 30 feet, and the breaker location, location of a large wave height decrease (red to green) follows this bathymetric contour very closely. As a result, these large waves also break closer to shore as one moves around the point to the north. Thus, severe storm waves are acting to erode the outer shelf of resistant rock which forms the base upon which Presque Isle sits.

DISCUSSION

Results from the wave analysis show that the northwest end of the island, in the vicinity of survey stations 3, 4 and 5, is exposed to the greatest wave energies occurring along the study area. Consistent with results of the wave analysis, the aerial photographic analysis also shows measurable losses of the bluff in this location, 0.7 feet per year on average for the area. Depite the relative strength and resistance to erosion of the Serpentinized peridotite present in this region, the area is subject to the largest long term erosion rates of the entire reach.

Along the middle portion of the study site, survey stations 6 and 7, very little erosion was measured, and in many cases no change occurred during the past 20 years. This area experiences less wave energy compared to the northern portion of the study site but the geology is similarly dominated by Serpentinized peridotite. In the vicinity of stations 8 and 9 the Jacobsville sandstone dominates the geology. The sandstone appears much less resistant to erosion than the Serpentinized peridotite. The sandstone in this location is easily removed and measurable rates of erosion occurred at nearly every transect except at the two southern most transects near survey station 9. However, erosion rates in this area are relatively small with only one transect line showing an erosion rate greater then one foot per year. Results of the wave energy analysis show much less wave energy impacts this portion of the study area than that to the north. Therefore, the low rates of bluff retreat are likely the result of lower wave energy.

Wind, wave, ice and human activity have caused erosion in the southern portion of the study area where the Jacobsville sandstone dominates the stratigraphy. Foot traffic down the bluff face has caused channelized flow down the bluff increasing erosion in localized areas (Figure 12A). In addition, construction of walkways, parking areas and removal trees and shrubs in and around the picnic area have increased runoff and caused channelized flown down the bluff (Fig 12D and E). In contrast, along the middle and northern portions of the study area where the Serpentinized peridotite stratigraphy is dominant, erosional forces of waves and ice dominate the erosional

process, not human activity. Two exceptions are the pipe extending from the bluff face between survey stations 3 and 4 (Figure 12B), and the culvert discharge channel between survey stations 5 and 6 (Figure 12C). At both of these locations, human caused erosion is exceeding erosion caused by waves and ice and is substantially greater then erosion rates of the surrounding bluff.

ALTERNATIVES

No Action Alternative- This alternative would not involve placement of any shore protection structures along the western shoreline of Presque Isle Park. The park will continue to erode within the study area at a rate similar to that identified in this report. Based on the average rate of erosion the existing road would not be in danger from erosion for approximately 15 to 20 years. At that time it will be necessary to either place shore protection or relocate the road further toward the center of the island. This alternative will have no impact on nearshore and coastal dynamics and will maintain the natural beauty of the park. From discussions with the Presque Isle Advisory Committee, this alternative appears to be consistent with trying to maintain the character of the park.

First Action Alternative- This alternative would involve relocating the existing park road along the western side of the park. The road should be located as far into the interior of the island as possible to eliminate the need to relocate road again within the foreseeable future. This alternative will have no impact on nearshore and coastal dynamics and will maintain the natural beauty of the park. From discussions with the Presque Isle Advisory Committee this alternative appears to be consistent with maintaining the character of the park. Cost of implementing this option is as follows:

- Road design and engineering and site management $15,000.00
- Tree removal for approximately 2400 feet of road $1,500.00
- Actual roadwork including grading $55.00 per lineal foot
- Landscaping after road construction $15.00 per lineal foot

Second Action Alternative- This alternative would involve placement of a revetment along the toe of the bluff within areas identified as having measurable erosion rates of greater then 1 ft. per year. The revetment could consist of up to several hundred lineal feet and be located along the northern half of the study area. This alternative will impact nearshore and coastal dynamics by absorbing incident wave energy and ice push. There will be no measurable adverse impact on adjacent properties as the bluffs supply little material for longshore transport. The physical appearance of the western shoreline of the park will altered. The revetment structure will consist of 2.5 to 5.0 ton rocks that will not be similar in structure or appearance to the natural shoreline. However, every effort should be made to design the least intrusive structure. Approximately cost of this alternative is $160 per lineal foot.

Among any of the alternatives it is recommended that storm water discharge along the west side of the park be addressed. This would involve elimination of direct and unrestricted discharge over the bluff face. Placement of check dams and drop structures could be used. The drop structure would have to be protected from both ice and wave attack. Cost of implementation is approximately $10,000.00.

In addition to addressing erosion caused by storm water discharge, erosion caused by pedestrian traffic must also be addressed. Planting trees and shrubs, and limiting pedestrian access to the beach in the picnic area can also assist in mitigating erosion. Providing designated access points, which are properly designed to minimize erosion yet provide access, and moving the main picnic area further away from the bluff, can reduce pedestrian related erosion. Cost of the vegetative plantings would be approximately $6,000, and cost of moving a portion of the picnic area would be approximately $5,000. It is also recommended that the remaining pavement from the old road, which is causing runoff, be removed and replaced with a more pervious trail and that shrubs be planted along the trail.

RECOMMENDATIONS

Based on the relatively slow erosion rates occurring along the west side of Presque Isle Park, and that there are no structures in immediate danger, we recommend that no shore protection be placed at this time. As an alternative to this nonstructural recommendation, and to slow the rate of shoreline retreat in the few areas experiencing erosion rates greater then 1ft. per year, and/or in areas where the road is in close proximately to top of the bluff, small revetments could be installed. We recommend that the revetments be placed above the state and federal ordinary high water mark elevations of 602.6 and 603.1 (IGLD 1985), respectively. Placement of the revetments above the ordinary high water marks will allow for construction without the need for state and federal permits, but will still afford protection to the bluff. Local soil erosion and sedimentation control permits may still be required. In general, the revetment should extend at least 20 feet either side of the region to be protected and to provide adequate structural stability. Figure 13 provides a conceptual diagram of revetment design considerations. This drawing provides information on the general structure and stone size of the revetments only, and is not intended to replace designs and drawings prepared and certified by a professional engineer.

It is recommended that best management practices for the stormwater runoff and planting of vegetation within the existing picnic area be initiated. As erosion gets closer to the road it is recommended that the road be relocated prior to placing shore protection. If erosion rates increase beyond expected or when the road can no longer be relocated landward, shore protection may be necessary. The Department of Environmental Quality and the United States of Army Corps. of Engineers look favorably on nonstructural alternatives as we recommend. At which time buildings or infrastructure are in danger from erosion, both agencies will look much more favorably upon a structural solution.

We also recommend that the existing monitoring program by Presque Isle Park Advisory Committee continue along the existing 14 sites presently being measured, and to expand the monitoring area further to the south. In the future, if there is substantial change in erosion rates from that found in this study it may be necessary to reevaluate the above noted alternatives.

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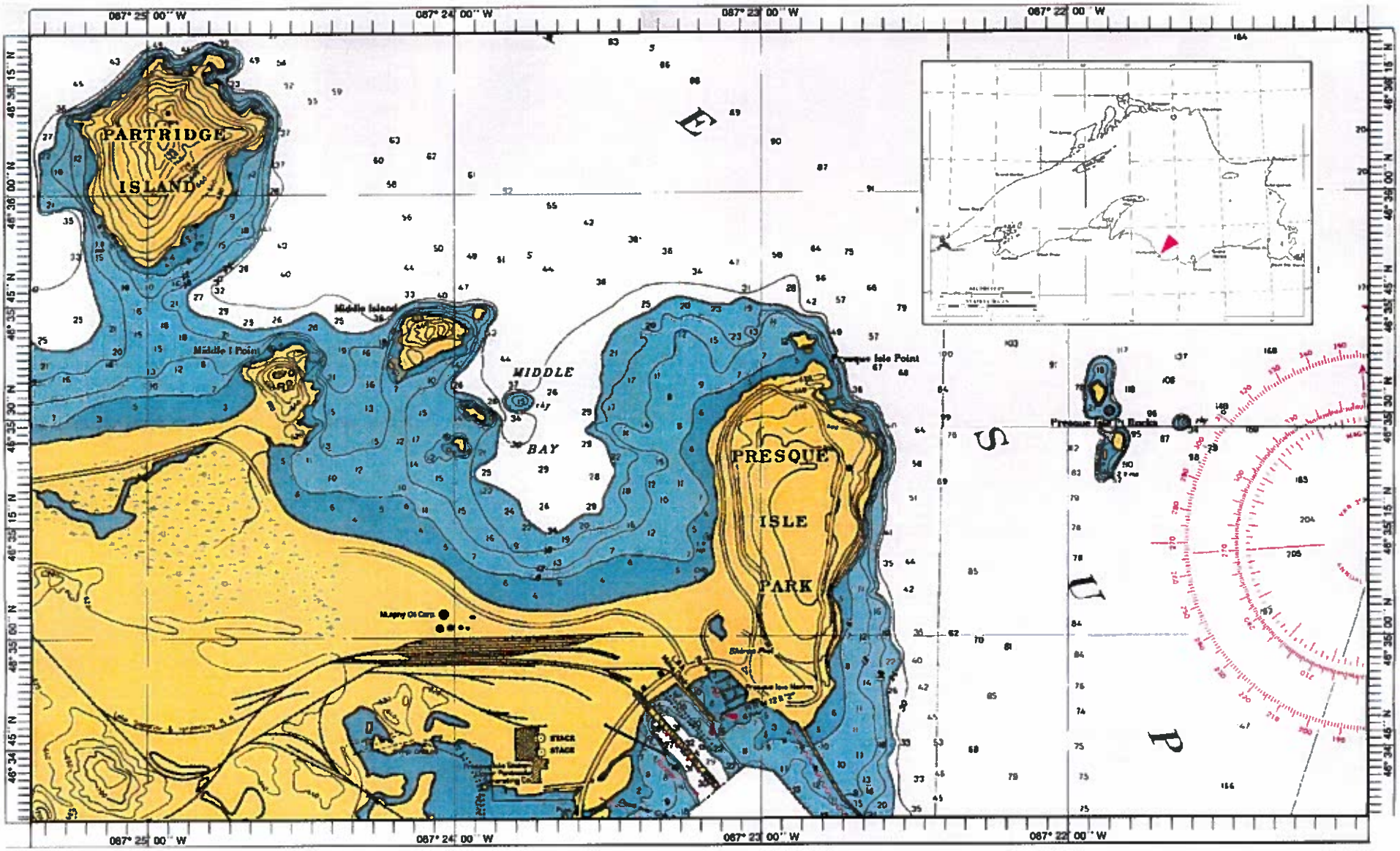


Figure 1. Site diagram showing Lake Superior (inset) location finder and 1994 NOAA Nautical Chart of Presque isle region.

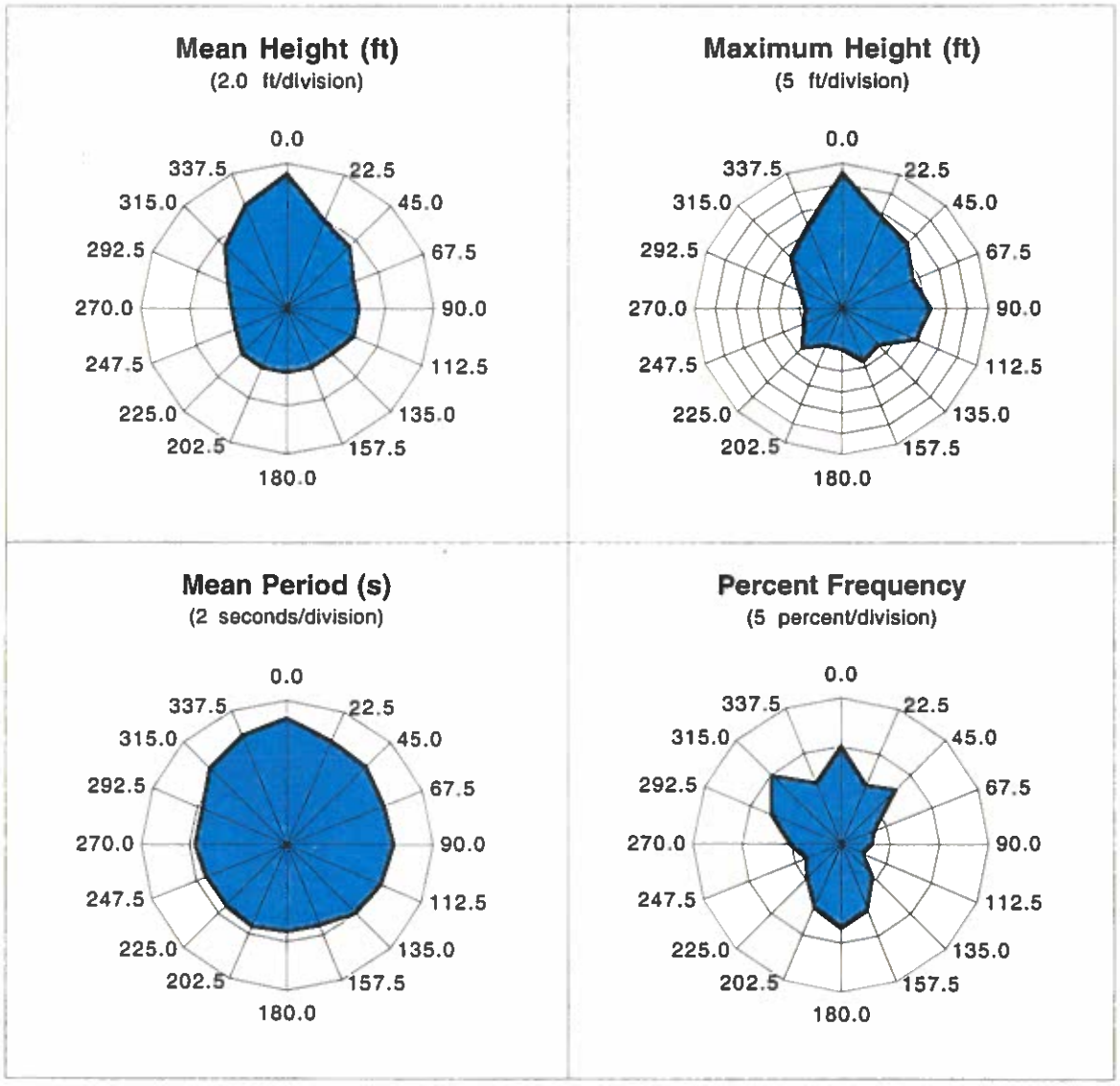


Figure 2. WIS station S46 deep water wave climtology.

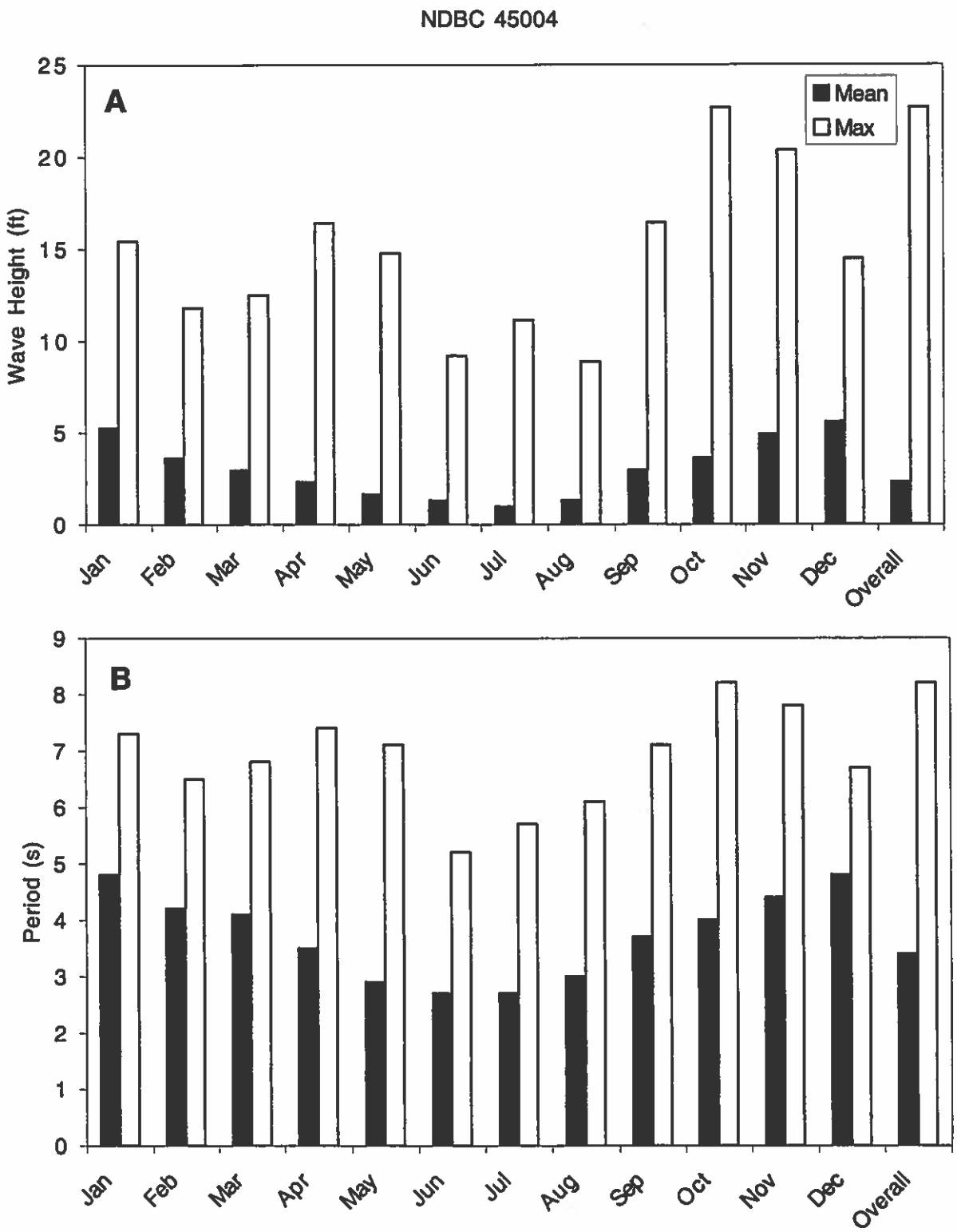


Figure 3. Monthly and overall wave statistics from NDBC buoy 45004, located in central Lake Superior.

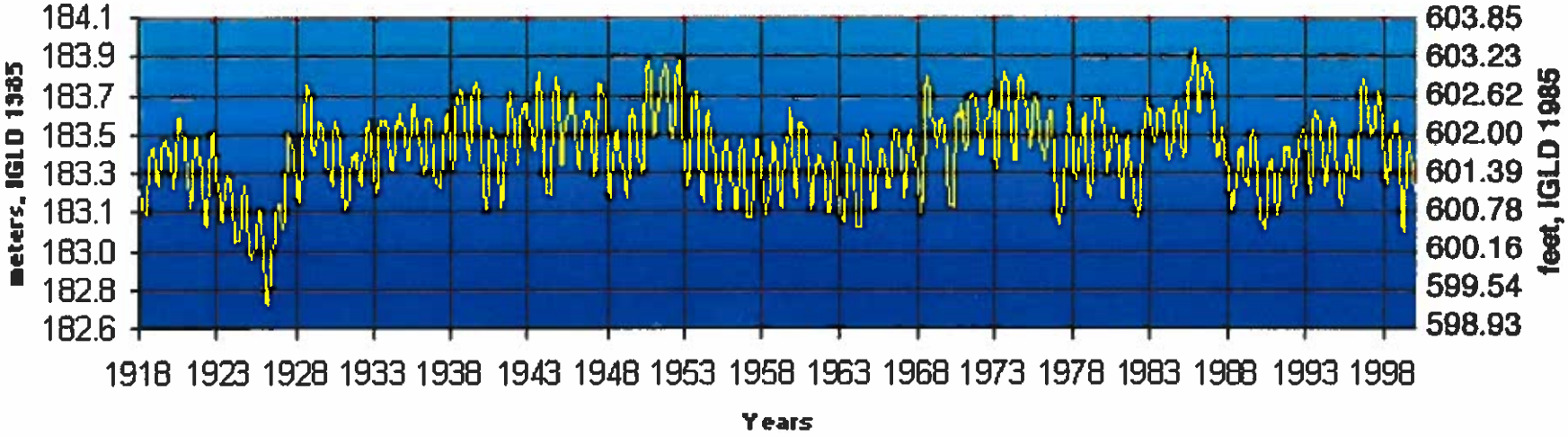


Figure 4. Lake Superior mean monthly water levels.

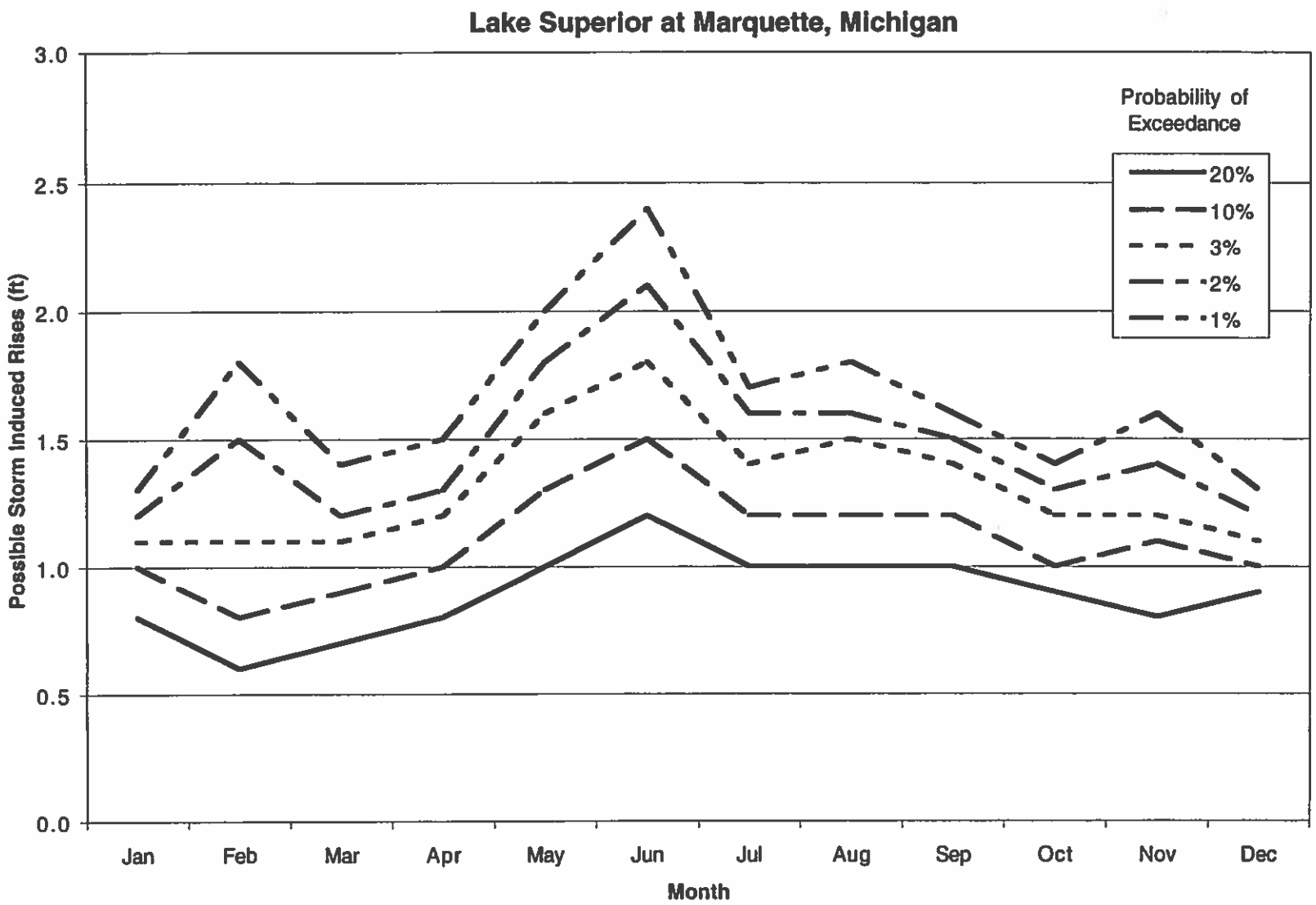


Figure 5. Probabily of exceedance values for storm induced water level rises at Marquette, Michigan.

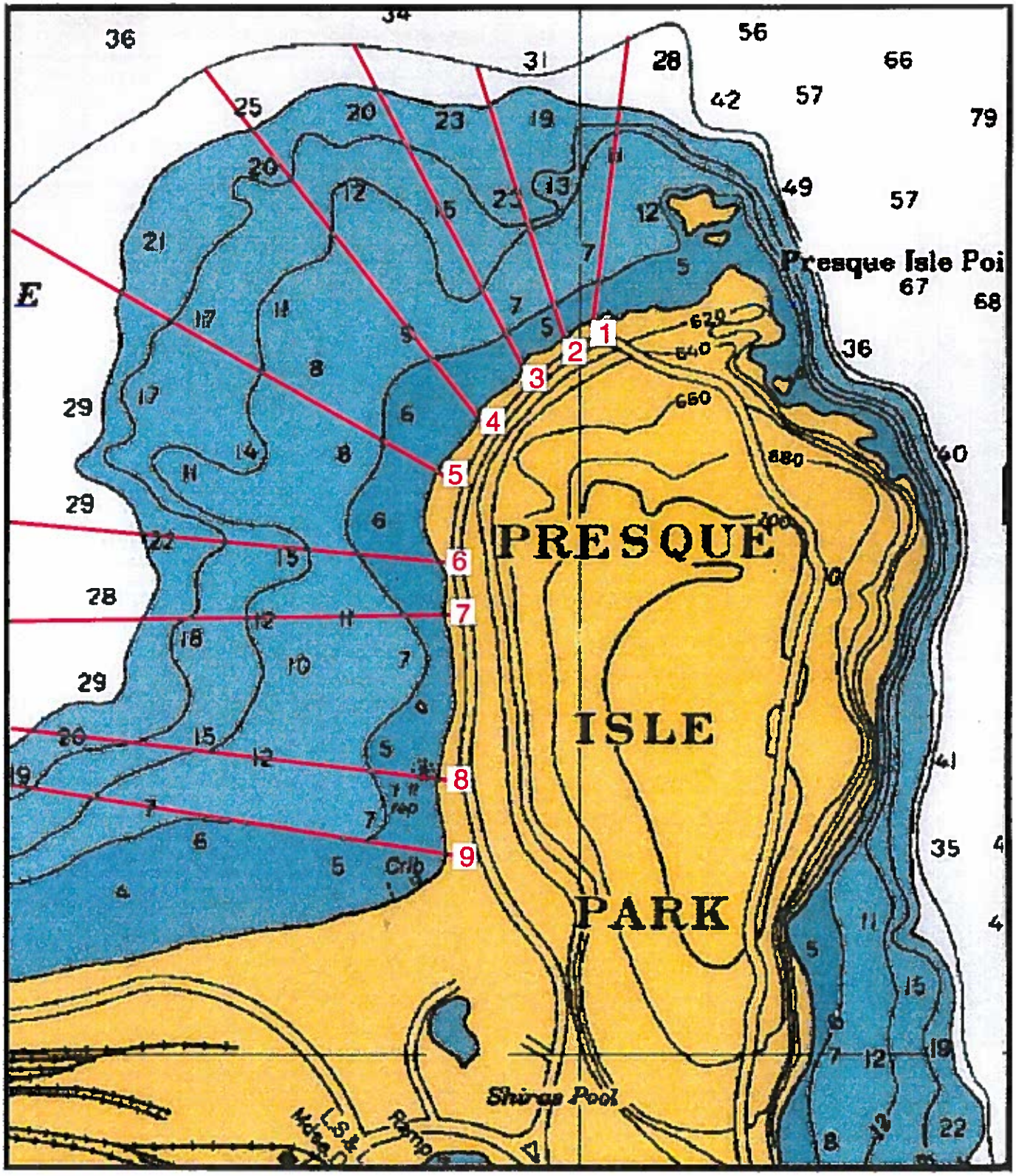
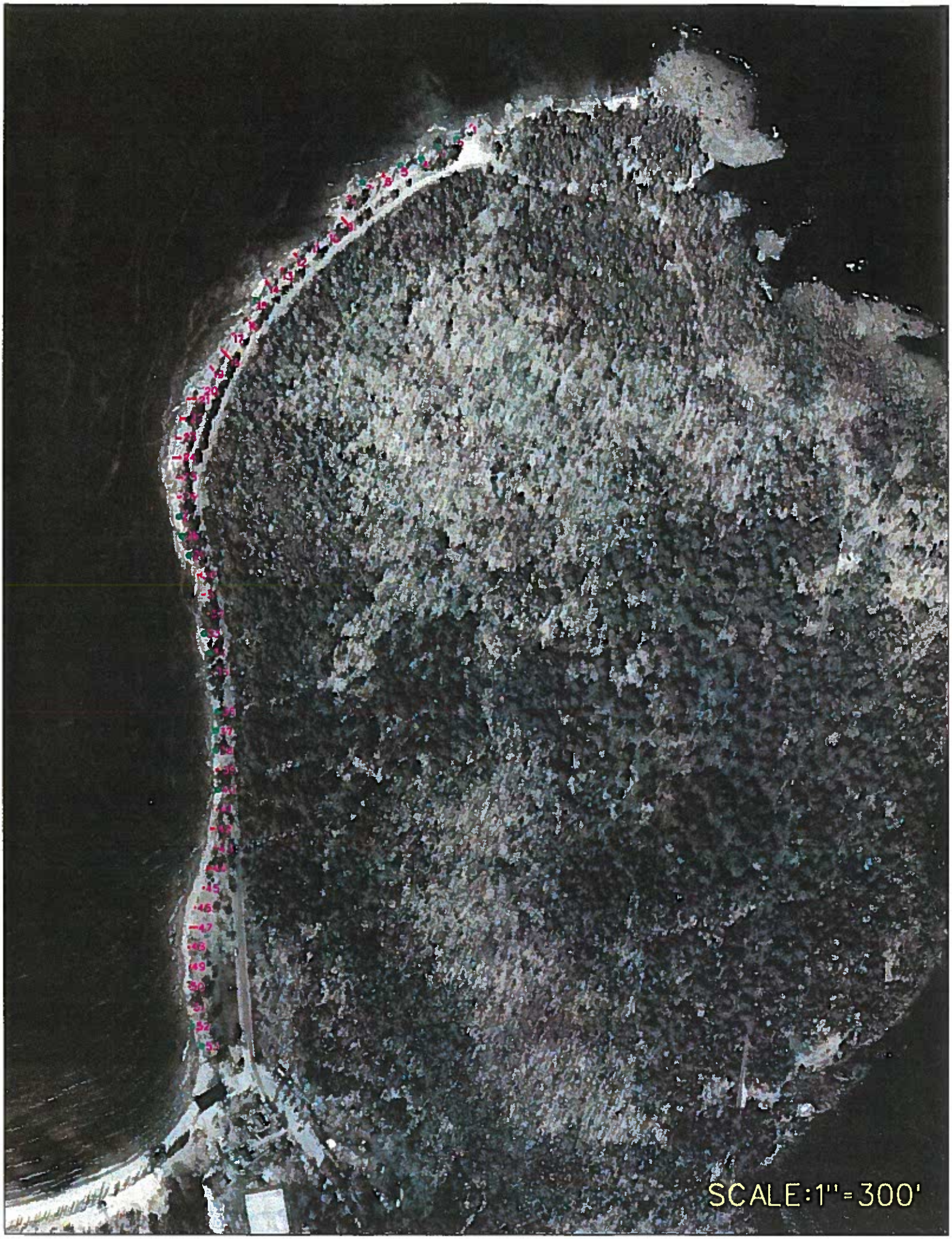


Figure 6. Map of Presque Isle showing precision nearshore hydrography survey sites.

Figure 7. Contour plot of bathymetric grid constructed from July 2000 survey data (depth scale in feet referenced to water on 11 July 2000).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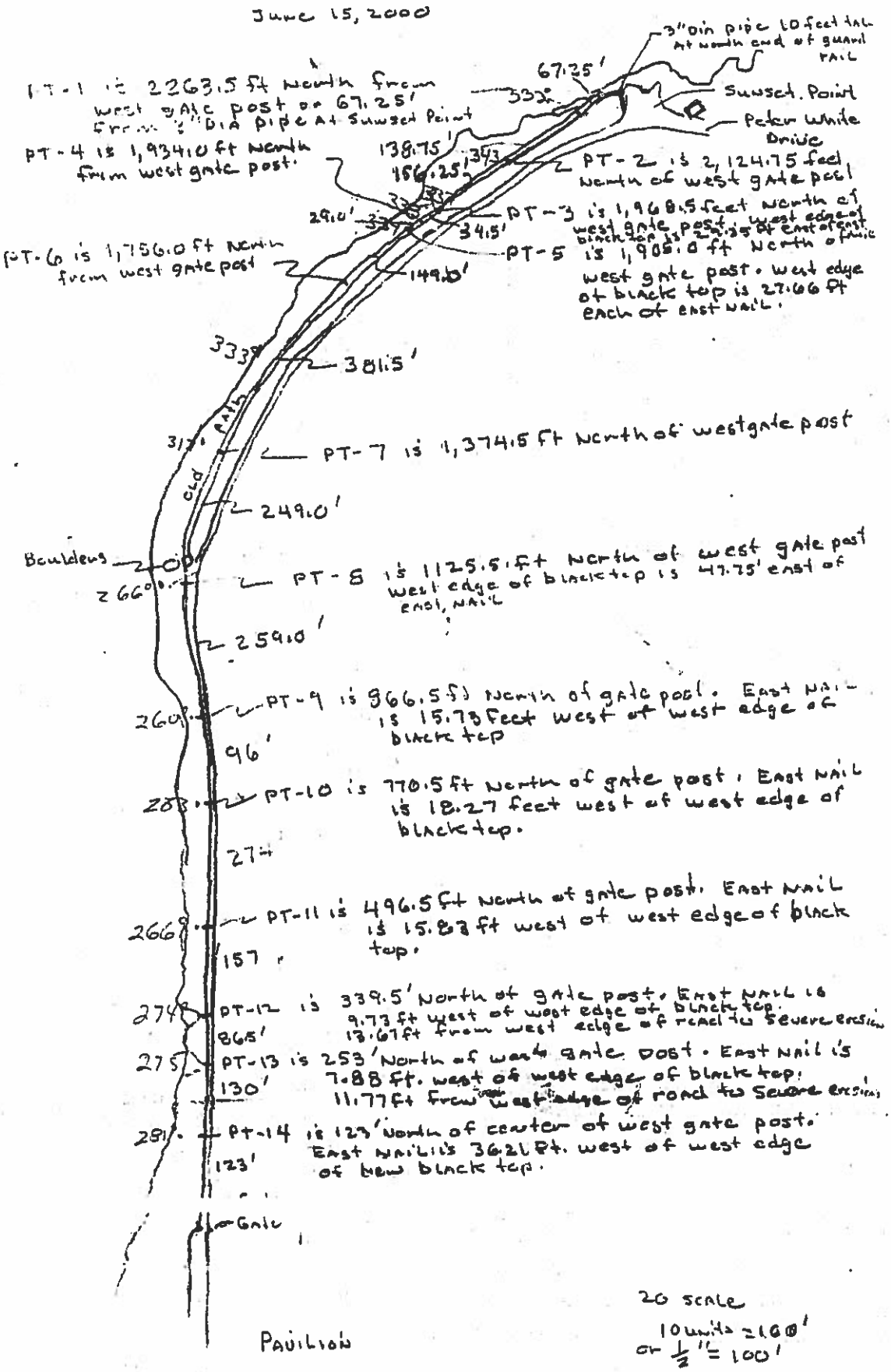


Figure 9. Diagram showing PIPAC shoreline change measurement site locations.

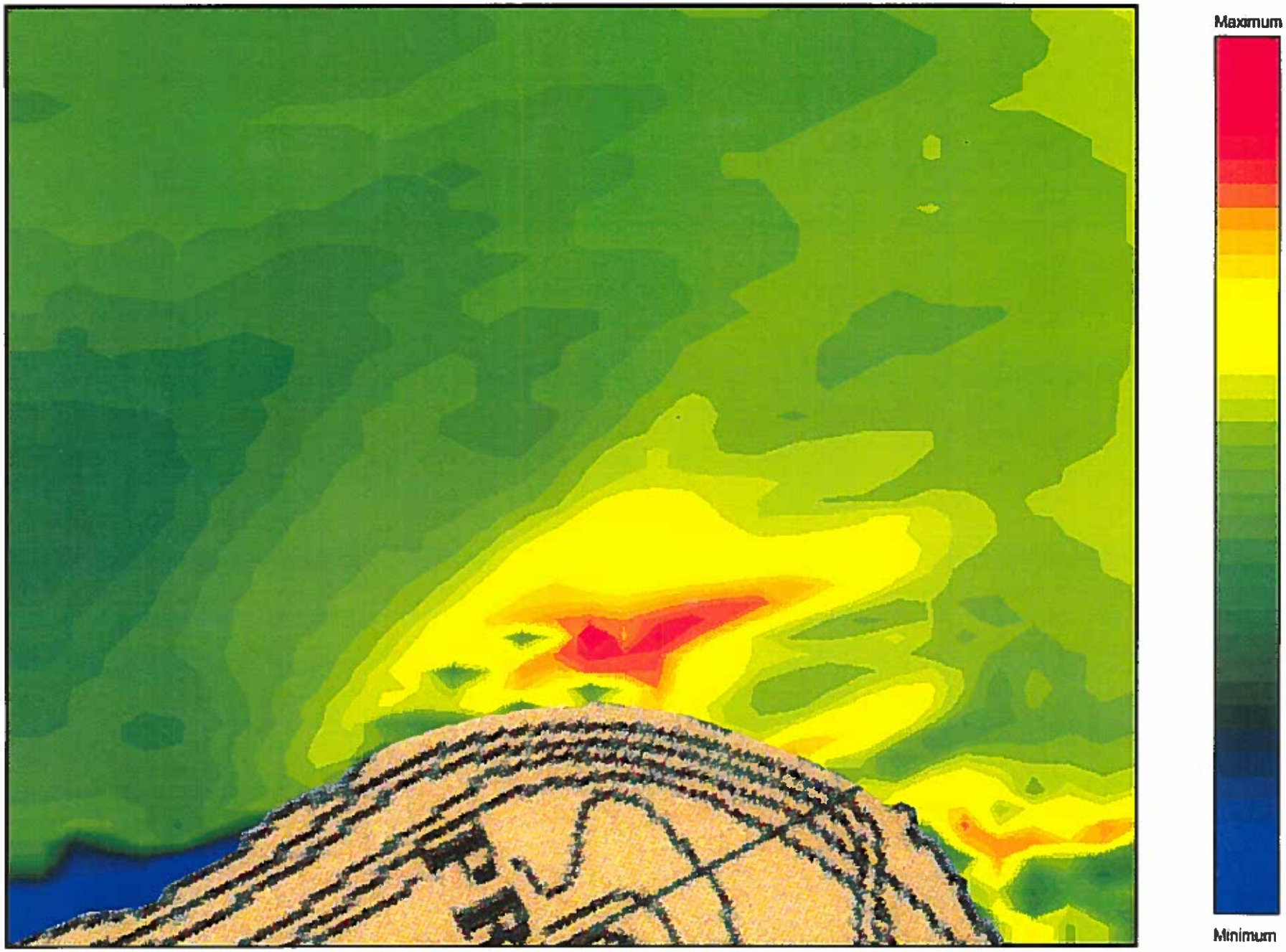


Figure 10. Relative wave energy near Presque Isle due to long-term average incident wave conditions

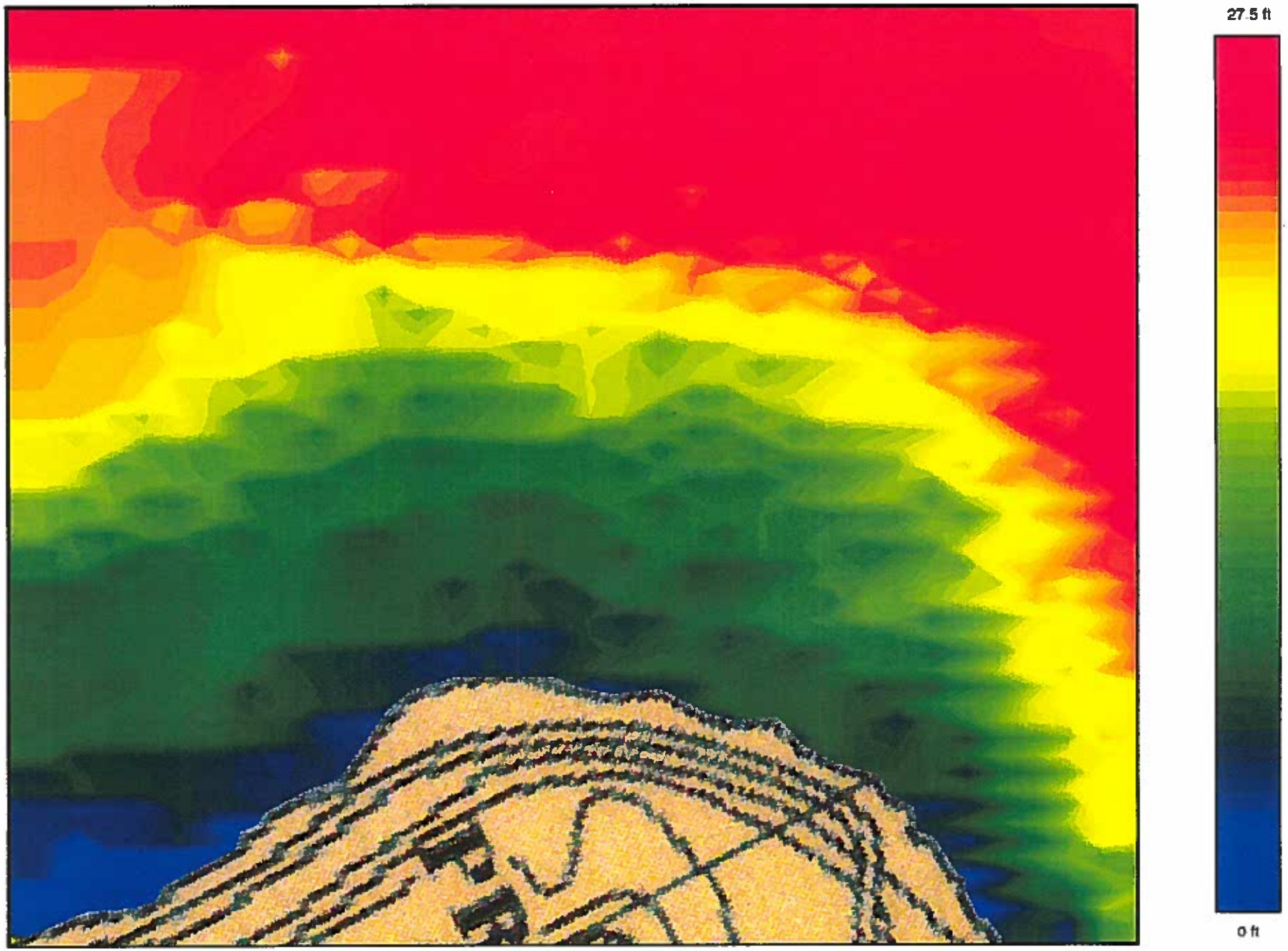


Figure 11. Modeled nearshore wave heights near Presque Isle due to extreme storm wave from the north.

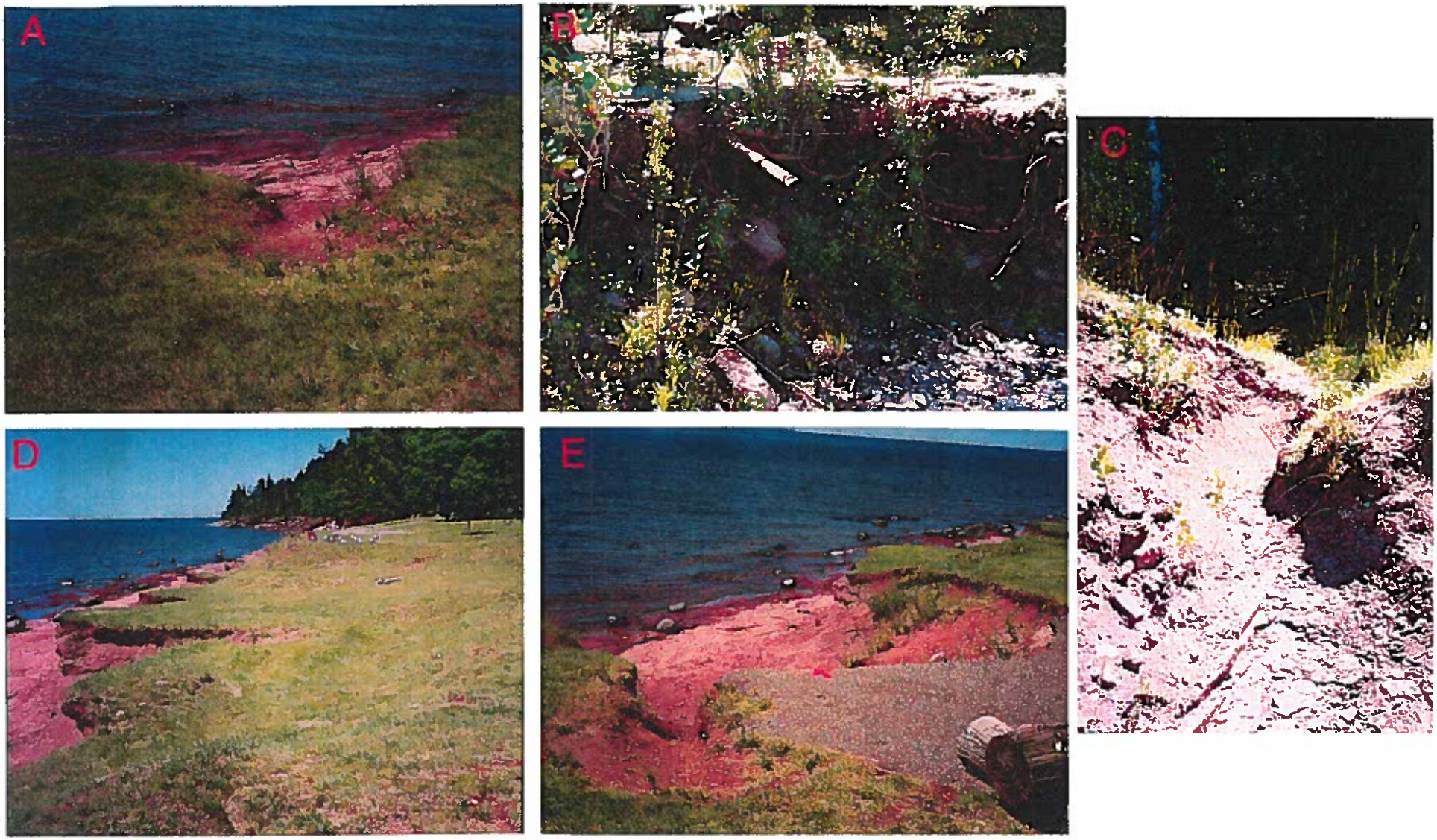
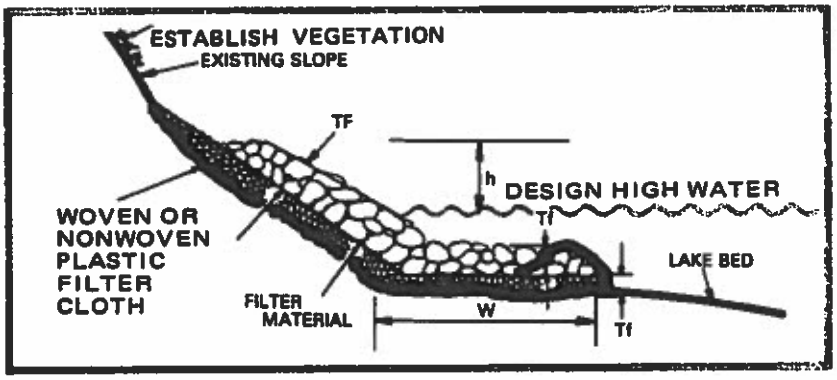


Figure 12. Photographs showing alternate sources of erosion.

STONE REVETMENT



Stone revetment is the preferred method of shore protection. It is economical and suitable for all types of erosion problems when stone is available in sufficient size and quantity. The key design considerations,are the dimensions, foundation treatment, and stone size. Construction is not complicated and no special equipment, other than a crane and trucks are needed.

NOTES:

1. Slope should be compacted and graded to 1:2 or flatter.
2. Place a gravel, small rock, filter blanket, and/or filter cloth on the prepared slope.
3. Place rock carefully with a crane; rock should be supported at three locations.
4. Insure rock sizes are well mixed. Larger and smaller rock should not be visibly segregated.

MAINTENANCE REQUIREMENTS

This structure is subject to displacement. The effectiveness of the structure will be impaired by thinning of the protective layer or settling of the structure. Restoration of the rock slope protection to the designed top elevation, equivalent thickness and reduction of voids in the facing should be accomplished when needed. The list of materials and general costs information is given in the following tabulation.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Thickness (ft)	2	4	5
Average Wt of Stone (#)	200 – 500	750 – 2000	2000 – 5000
Height of Structure (ft)	4	6	8
Toe Protection Width (ft)	2	4	5
Filter material	Cloth		
List of Materials (per ft)			
Stone (tons)	1.89	4.94	7.36
Filter (sq ft)	13	19	22
Cost $/Lin. Ft.	50	130	230

ADVANTAGES

Most effective structure for absorbing wave energy.

Flexible—not weakened by slight movements.

Natural rough surface reduces wave runup.

Lends itself to stage construction.

Easily repaired—low maintenance cost.

The preferred method of protection when rock is readily available at a low cost.

DISADVANTAGES

Heavy equipment required for construction.

Limits use and access to beach.

Moderately high first cost.

Difficult to construct where access is limited.

Figure 13. Typical stone revetment design considerations (from USACE, "Help Yourself" Manual).

Table I. Erosion measurements for each transect line obtained from comparing difference in bluff location from 1977 and 1997 aerial photographic analysis.

Transect No.	Measurement (ft.)	Avg. Loss (ft./yr.)
1	4	0.2
2	0	0.0
3	0	0.0
4	0	0.0
5	0	0.0
6	9	0.4
7	0	0.0
8	4	0.2
9	19	0.9
10	5	0.2
11	4	0.2
12	15	0.7
13	9	0.4
14	14	0.7
15	0	0.0
16	8	0.4
17	3	0.1
18	31	1.5
19	15	0.7
20	3	0.1
21	24	1.2
22	18	0.9
23	14	0.7
24	23	1.1
25	15	0.7
26	10	0.5
27	0	0.0

Transect No.	Measurement (ft.)	Avg. Loss (ft./yr.)
28	0	0.0
29	0	0.0
30	11	0.5
31	10	0.5
32	6	0.3
33	0	0.0
34	0	0.0
35	8	0.4
36	0	0.0
37	0	0.0
38	0	0.0
39	15	0.7
40	0	0.0
41	7	0.3
42	16	0.8
43	14	0.7
44	15	0.7
45	5	0.2
46	4	0.2
47	21	1.0
48	6	0.3
49	6	0.3
50	3	0.1
51	2	0.1
52	0	0.0
53	0	0.0

Table II. PIPAC on-site erosion measurements November 13, 1998 through June 16, 2000.

Transect No.	Avg Loss (ft/yr)	Closest Air Transect
1	2.30	2
2	1.45	6
3	0.66	9
4	0.41	9
5	0.45	10
6	0.49	12
7	0.13	20

Transect No.	Avg Loss (ft/yr)	Avg. Loss (ft./yr.)
8	0.19	25
9	0.16	30
10	0.00	32
11	0.30	37
12	0.15	40
13	0.16	42
14	0.21	44