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Weko Beach Shoreline Erosion Study

Bridgman, Michigan

September, 1981

WILLIAMS & WORKS
ENGINEERS/PLANNERS/ARCHITECTS
GRAND RAPIDS, MICHIGAN 49506

WEKO BEACH

SHORELINE EROSION STUDY

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SECTION I - GENERAL

INTRODUCTION

The Weko Beach Recreational Area is located in the northwest corner of Section 16, City of Bridgman, Berrien County, Michigan. The recreational area shown on Figure 1 has approximately 3,000 feet of shoreline, and is entirely within the coastal boundary as defined by the Michigan Coastal Zone Management Program. The unique features of the site include sand dunes and a natural Lake Michigan beach. The recreational area also contains camping/picnic facilities, a swimming area and beach house, and a boat launch ramp. The property is owned by the City of Bridgman. The city water intake is located about 200 yards offshore of the swimming beach.

The beach area has been experiencing normal erosion for many years. In the early 1970's, the erosion accelerated, due in part to record high lake levels. In 1973, the beach had been reduced to less than 50 feet wide in front of the beach house. In an attempt to protect this structure, small rubble groins were placed along the shore, and two sheet pile walls were constructed. These measures were partially successful, and lower lake levels resulted in a slight widening of the beach. By 1981, these temporary structures were in poor condition, and were removed under the Michigan Coastal Zone Management Program.

PURPOSE AND METHODOLOGY

The purpose of this study is to analyze the shoreline erosion at Weko Beach, and evaluate the feasibility of providing a long-term solution to the erosion problem. The work was conducted under contract with the City of Bridgman, and was partially funded by the Michigan Coastal Zone Management Program. The investigation specifically emphasized three problem areas.

1. Protection of the Weko Beach House
2. Improvement of the boat launch ramp
3. Protection of the fresh water intake and sub-bottom pipeline

The study involved the following work tasks.

1. Collection of Data and Information
2. Analysis of Historical Shoreline Erosion
3. Evaluation of Current Shoreline Situation
4. Evaluation of Alternative Shoreline Erosion Control Measures
5. Recommendations for Weko Beach
6. Report Preparation

Figure 1
WEKO BEACH PROJECT VICINITY

Throughout the study, low-cost shoreline improvements were given principal consideration, due to the limited financial resources available for shoreline projects.

SITE DESCRIPTION

The major features of the site are shown on Figure 1. The main access road terminates at the beach house with parking provided on both sides of the road. The beach house contains restroom facilities, a snack bar, and a large game room. The lower level of the building is located on the beach, approximately 75 feet from and 5 feet above the water's edge (1981).

The single lane boat launch ramp, located at the northern end of the property, is partially protected by a low sheet pile jetty on the north and a short rubble groin to the south. In spite of these structures, sand continaully covers the launch ramp, necessitating periodic cleanup. The material is carried by both the water currents and wind. Sediment deposition problems such as this are almost impossible to avoid at open coast locations.

The swimming beach extends from the launch ramp to the south for a distance of 3,000 feet. The first 1,200 feet, between the launch ramp and water intake, varies from 75 to 125 feet wide. Two small groins, extending less than 20 feet into the water, protect the water intake pipeline. The section of beach between these groins and the launch ramp extends farther seaward than the adjacent shoreline, indicating that the structures have trapped sand moving along the shore (littoral material).

To the south of the water intake, a wide (200 feet) beach extends for 1,800 feet to the property line. This area is extensively used for swimming and beach activities.

Behind the beach on both sides of the access road is a sand bluff, which is undergoing moderate erosion. Measures to control this problem are being investigated under another program.

The fresh water intake for the City of Bridgman is located immediately offshore. Water is pumped from beneath the sandy lake bottom to the water treatment plant about 1/4 mile inland. In the past, concern has been expressed regarding the stability of the pipeline from the intake structure to the shore. At present, the pipe is well covered with stable sand, and no problems are anticipated.

ENVIRONMENTAL CONDITIONS

Shoreline erosion or accretion is dependent upon the interaction of many environmental factors. These include wind and wave forces, water level variations, and ice. A brief overview of these conditions at Weko Beach is given on the following page.

Lake Levels -- Fluctuations in the lake level may cause an extensive alteration of shoreline conditions. As the water level rises, waves more frequently cross the previously stable beach, causing erosion of a shoreward bank. This process frequently results in undercutting of steep bluffs and sloughing. For a beach system, the effects of rise and fall in water level do not balance. High water levels permit erosion of the bluffs whereas during periods of low water level, these shoreline features are not replaced. Even a wide protective beach will readjust to higher water levels by erosion of the berm and accretion offshore. The changing lake level also upsets the previous shoreline balance by permitting larger waves to break closer to shore.

The beach material in the wave breaking zone is moved more readily than material offshore, which will only be subjected to oscillating, non-breaking wave forces. A beach face will therefore readjust quickly to a change in water level conditions, but offshore areas will adjust more slowly.

The orientation of the shoreline will not be significantly affected by variations in water level unless refraction of the waves is altered; that is, unless irregularities in bed topography occur through exposure or inundation of beach material.

In the Weko Beach area, the Lake Michigan water level varies both seasonally (1-2 feet) and long-term. The maximum Lake Michigan level was recorded in June, 1973, at 580.9 feet (International Great Lakes Datum). The average lake level is 578.3 feet (IGLD). Low water datum (LWD) is 576.8 feet. In the following section, the significance of lake level variations on historical shoreline position is shown.

Waves -- The dominant forces involved in shoreline erosion are winds and waves. Breaking waves impart energy upon the shoreline, resulting in erosion and transport of beach material. At Weko Beach, the larger, steeper waves, created by strong northerly winds, are the most effective in eroding and moving sedimentary material. Smaller (less steep) waves tend to push sediment onshore and aid in building the beaches. It is the relative frequency of wave heights and directions that determine the net effect on a shoreline.

The wave "climate" for a particular area depends on the winds, the distance over which the wind blows (fetch) and the shore and bottom configuration. In the area offshore of Weko Beach, waves up to 10-12 feet have been observed (Reference 1). However, it is the waves breaking nearshore that cause longshore movement of sand. The relatively flat offshore slope of the beach at Weko results in the larger waves breaking far offshore (a wave will break in water depth approximately equal to the height of the wave). Therefore, the large waves are not a major factor in sand transport along the beach.

From analysis of the waves as they approach the shoreline, 3-4 foot breaking waves are the maximum waves that cause sediment transport. These waves result from northwest storms, and occur two to four times each year. The shoreline responds quickly to these events, followed by a gradual return to the equilibrium situation.

Winds -- Winds act directly upon beaches by creating shear forces upon the individual sand particles and thereby blowing sand off the beach (deflation) or depositing sand in dunes. Winds move sand in three ways: 1) suspension where small particles are lifted and held in the air stream; 2) saltation where particles are carried in a series of short jumps; and 3) surface creep where particles roll or bounce along the beach. Most particles move by saltation. Sand moved seaward usually falls into the wave breaking zone and, although lost to the beach, still remains in the littoral transport zone.

Ice -- An ice cover along the shoreline can substantially reduce erosion by reducing the wave energy imparted to the shore. For this reason, the analysis of littoral drift is usually conducted only for ice-free periods.

SECTION II - SHORELINE EROSION ANALYSIS

GENERAL

The behavior of any reach of shoreline is dependent upon complex relations between the numerous elements that make up that section of the shore. Such factors as the natural forces that erode and transport material, the amount of material available for the erosion or accretion, and the works of man in the form of structures or other unnatural disturbances to the shoreline balance must be considered.

The basic mechanism for erosion on the Great Lakes involves the constant wearing away of the coast from wave attack on the shoreline over geologic time. Wave attack breaks down the larger source rocks into small materials which can be raised into suspension in the water and carried away by longshore currents (suspended load). Material that remains too large to be raised in suspension may be moved along the bottom by wave forces (bed load). This movement of sediment in the nearshore region is called littoral drift. Net erosion within a specific reach of shoreline occurs when more material is transported from the reach than is input into it, whereas net accretion results from a surplus of input material. Creation of beach material in this manner requires many years.

The amount of erosion and/or sediment transport occurring within the shoreline reach depends upon the incident waves, material quantity and composition, and shore slope. The volume of material within a shoreline reach may be complemented by external source material from adjacent reaches or the offshore zone.

The source of material for Weko Beach is primarily the bluffs and beaches to the north. During the past twenty years, man-made structures have interfered with the natural north to south flow of sand in the area, thereby reducing the amount of material available for building or maintaining a beach. The evidence of this is shown in the analysis of aerial photographs presented later.

PRIOR STUDIES

Over the past ten years, a number of shoreline erosion studies have been conducted for the eastern shore of Lake Michigan (see references 2, 3, 4.). The recession of bluff and beach shorelines has been well documented for many areas. However, there have been no prior studies of the sand beach at Bridgman.

A Michigan Department of Natural Resources study in 1978 measured bluff recession rates for areas immediately north and south of Weko Beach. The erosion was characterized as moderate, in the range of one to three feet per year.

The most relevant study was completed by the Coastal Engineering Research Center in 1980 (reference 2). This investigation looked at several sites in the Berrien County area, and analyzed a series of aerial photographs for bluff and beach erosion. The results documented the severe bluff erosion, up to 10-20 feet per year in some locations.

For the purposes of this study, prior work provides insight into the erosion processes in the area, but does not provide useful information for the specific Weko Beach site. Therefore, a detailed analysis of the historical shoreline erosion at this site was performed.

HISTORICAL SHORELINE CONDITIONS

The objectives of this analysis were:

1. Provide a record of shoreline alignment changes over the past forty years.

2. Document the behavior of the shoreline with respect to lake levels and structural improvements.

3. Provide a basis for predicting future shoreline changes.

Methodology

The first step in the analysis was to obtain historic data on the Weko Beach shoreline position and Lake Michigan water levels. Eight aerial photographs of the beach were obtained from the U.S. Army Corps of Engineers and Soil Conservation Service, covering a time period from 1938 to the present. Actual recorded water levels were obtained from NOAA for the corresponding date of each photograph. The shoreline photographs, with corresponding water levels, are shown on Figure 2.

A baseline was established parallel to the shoreline, using objects common to several photographs as reference points. Stationing was established along the baseline, as shown on Figure 1, covering approximately 3,000 feet. The distance from the shoreline to baseline was then measured on each photograph at selected station locations.

The third step involved adjusting the measured shoreline positions, photographed as they appeared at various lake levels, to a single lake level as a common basis of comparison. The mean Lake Michigan level of 578.3 was selected for this purpose. These adjustments were made assuming the slope of the shoreline did not change significantly over the years. These adjusted shoreline positions are shown in Figure 3.

After adjusting the shoreline positions to a common water level, the yearly change in feet per year was determined at each station for periods between photography dates. It was also possible to calculate the total and annual

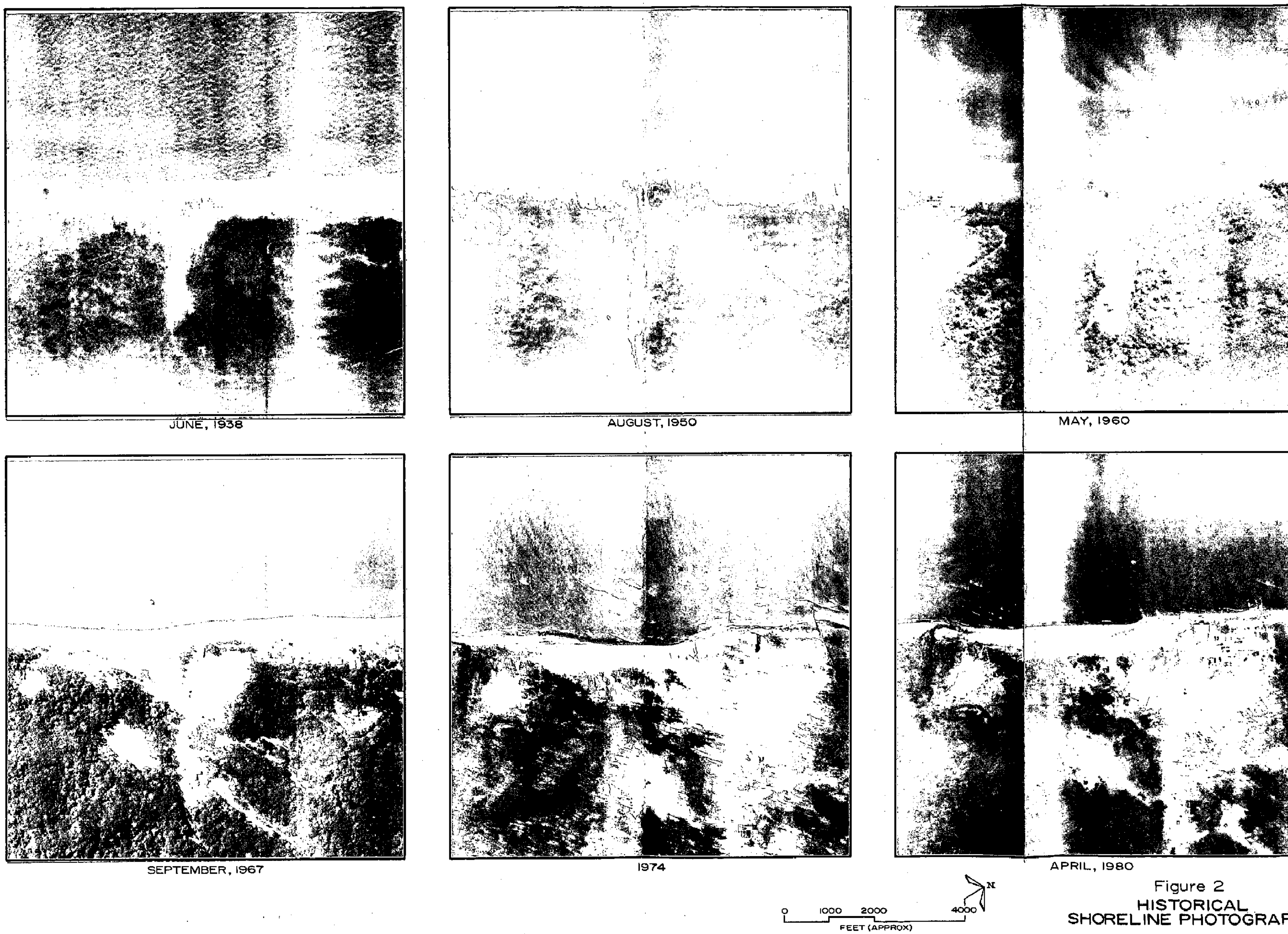

Figure 2
HISTORICAL
SHORELINE PHOTOGRAPHS

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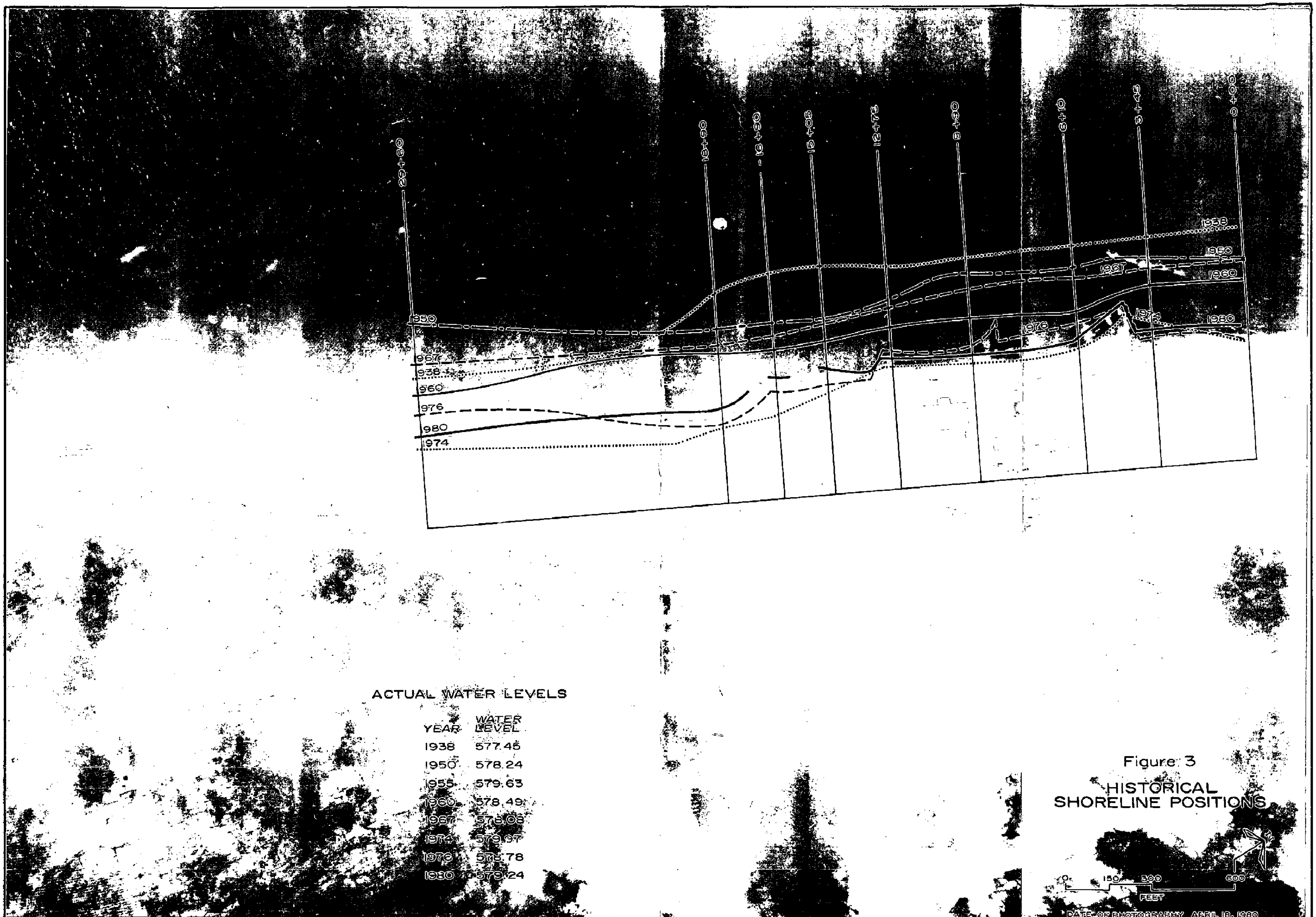

ACTUAL WATER LEVELS

YEAR	WATER LEVEL
1938	577.45
1950	578.24
1955	579.63
1960	578.49
1967	578.08
1974	579.97
1976	578.78
1980	579.24

Figure 3
HISTORICAL SHORELINE POSITIONS

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volume of beach material eroded or accreted. A typical beach slope value of 1:20 was assumed. The difference between the top of berm elevation and limiting depth (lakeward limit of sediment transport) was assumed to be 14 feet. These simplifying assumptions allowed the cross sectional area of sand movement to be calculated as the area of a parallelogram with a height of 14 feet and width equal to the positional change of the shoreline in feet. The change in volume of material between stations was then calculated using the average end area method.

The azimuth of the shoreline (angle measured clockwise from north) was also noted at each station to aid in evaluating shoreline response.

Results

The analysis of the historical photographs and adjusted shoreline positions (Figures 2 and 3) shows a significant variation in the shoreline over the past forty years. A general pattern of long-term erosion is evident. In 1938, the beach in front of the beach house was over 500 feet wide. By 1960, the beach width had been reduced to 250 ft. Further erosion continued until 1974, when the beach was only 60-70 feet wide. This long-term erosion is a natural phenomena for an open, unprotected beach. High lake levels, such as the record levels of the early 1970's, increase the erosion. As the lake levels fell or stabilized in the late 1970's, the beach accreted slightly, aided by the small protective structures built during the high lake period.

The change in shoreline position at each station and the change in sand volume between stations are shown in Table 1. Four time intervals are shown, corresponding to periods of erosion or accretion. Total changes for the period as well as average annual variations are indicated. It is emphasized, however, that beach erosion is sporadic, depending upon the occurrence of major storms. It is estimated that over 75% of beach erosion occurs during these relatively infrequent events (35 per year). Therefore, average annual values are only indicative of long-term trends.

The data indicate that the most severe erosion occurred in the period from 1967-1974. Over 200 feet of beach was lost. The average erosion during this time was almost double the rate experienced between 1938 and 1955. It is likely that most of this occurred in 1971-1974, when lake levels rose rapidly. Over the entire 3,000 foot reach of shoreline, over 330,000 cubic yards of material was lost. About 46,000 yards of this material was returned to the beach between 1974 and 1980, with most of the gain occurring in the western half of the reach.

The erosion pattern at Weko Beach has resulted from a number of factors. The relative frequency of storm events and water level of Lake Michigan are the two most significant natural factors. The construction of facilities along the shoreline and attempts to protect the beaches and bluffs with seawalls,

TABLE 1

SUMMARY OF HISTORIC SHORELINE ANALYSIS

STATION	1938--1955 Shoreline Position[1]: Total Change, FT	1938--1955 Shoreline Position[1]: Average Change per Year FT/YR.	1938--1955 Volume[2]: Total Change in Volume, YD^3	1938--1955 Volume[2]: Average Change per Year YD^3/YR.	1955--1967 Shoreline Position[1]: Total Change, FT	1955--1967 Shoreline Position[1]: Average Change per Year FT/YR	1955--1967 Volume[2]: Total Change in Volume, YD^3	1955--1967 Volume[2]: Average Change per Year YD^3/YR
29+60	-69	-4.0			105	8.4		
			-82,660	-4,840			47,710	3,810
18+90	-229	-13.4			67	5.4		
			-28,370	-1,660			9,400	750
16+90	-318	-18.6			114	9.1		
			-31,650	-1,850			12,380	990
15+05	-342	-20.0			144	11.5		
			-31,840	-1,860			11,980	960
12+75	-192	-11.2			57	4.6		
			-33,180	-1,940			14,850	1,190
9+90	-257	-15.0			144	11.5		
			-47,880	-2,800			26,800	2,140
6+10	-229	-13.4			128	10.2		
			-28,030	-1,640			14,910	1,190
3+45	-179	-10.5			89	7.1		
			-34,790	-2,040			17,080	1,360
0+0	-210	-12.3			102	8.2		

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[1] Ft from baseline adjusted to mean lake level; lakeward change positive

[2] Accretion positive

TABLE 1 (Cont'd.)

SUMMARY OF HISTORIC SHORELINE ANALYSIS

	1967--1974				1974--1980			
	SHORELINE POSITION[1]		VOLUME[2]		SHORELINE POSITION[1]		VOLUME[2]	
STATION	TOTAL CHANGE, FT	AVERAGE CHANGE PER YEAR FT/YR.	TOTAL CHANGE IN VOLUME, YD^3	AVERAGE CHANGE PER YEAR YD^3/YR.	TOTAL CHANGE, FT	AVERAGE CHANGE PER YEAR FT/YR	TOTAL CHANGE IN VOLUME, YD^3	AVERAGE CHANGE PER YEAR YD^3/YR
29+60	-282	-43.4			47	7.5		
			-152,010	-14,980			28,570	4,570
18+90	-266	-40.9			56	9.0		
			-26,180	-4,030			8,080	1,290
16+90	-239	-36.8			100	16.0		
			-20,860	-3,205			7,200	1,150
15+05	-196	-30.2			50	8.0		
			-20,635	-3,180			1,960	310
12+75	-150	-23.1			-17	-2.7		
			-25,270	-3,892			-1,920	-310
9+90	-192	-29.5			-9	-1.4		
			-38,725	-5,965			-2,760	-440
6+10	-201	-30.9			-19	-3.0		
			-20,890	-3,220			-8,720	-1,400
3+45	-103	-15.8			-108	-17.3		
			-26,840	-4,130			-11,720	-1,870
0+0	-197	-30.3			-23	-3.7		

[1] Ft from baseline adjusted to mean lake level; lakeward change positive

[2] Accretion positive

groins, and breakwaters has also had a major effect. Structures that interrupt flow of sand along the shore inevitably deprive downdrift shores of material, resulting in accelerated erosion. To the north of Weko Beach, numerous structures have been built, particularly in the 1960's and early 1970's. These have ranged from small groins to major installations (Cook Nuclear Plant, completed in 1974). These structures have no doubt deprived Weko Beach of some sand. The exact amount of loss is impossible to determine.

One interesting observation from the recent aerial photographs is that the beach between stations 3+45 and 16+90 extends farther seaward than the adjacent shoreline. This indicates that the existing small structures at Weko Beach are serving their intended purpose. Without the two groins at stations 16+00 and 17+00, and the steel sheet-pile jetty at the launch ramp (3+50), the beach would be expected to erode up to 50 feet. This would threaten the beach house. Therefore, it is imperative that these structures remain intact.

The orientation of the shoreline over the past forty years is shown on Table 2. It is apparent that shoreline orientation is quite variable, particularly at stations in the vicinity of the groins (e.g. 16+90). The shoreline angle is primarily dependent on the angle of attack of the most recent erosive waves. The values can be used to predict how the beach will respond to any proposed structural improvements.

LITTORAL MATERIAL AND TRANSPORT

The erosion and accretion processes described above are the result of an imbalance between sand being transported to an area and sand removed from the area. If more material is removed than is brought into an area, erosion results. The principal sources of beach material for Weko Beach are the eroding bluffs and dunes to the north. Depending on bluff type, 20% to 30% of the eroded bluff material is suitable for beach building. Beaches in the Weko area are medium to fine quartz sand (reference 2).

The net sand transport at Weko Beach is to the south, since the largest waves come from the north and northwest. Movement of sand from south to north are common during periods of southerly winds. The Corps of Engineers has estimated that a net southerly transport of approximately 100,000 cubic yards may occur in an average year (reference 4). However, this value represents the potential transport of material, assuming sand is available in the littoral system. With the numerous shoreline structures to the north, the supply of sand is limited.

The critical point is whether there is sufficient sand entering the system from the north to maintain the existing beach. Only a small portion of the theoretical 100,000 cubic yards is needed to maintain equilibrium. The slight accretion of the beach during the past few years indicates that a stable equilibrium has been reached, particularly for the critical area in front of the beach house.

TABLE 2

ORIENTATION OF SHORELINE

AZIMUTH ANGLE IN DEGREES

STATION	1938	1950	1955	1960	1967	1974	1976	1980
29+60	28	35	15	25	31	38	33	26
18+90	10	29.5	36.5	27.5	25	11.5	25.5	20.5
16+90	15	28	30	29	20	6.5	25.5	25.5
15+05	27	23	26.5	26	20.5	3	26	37
12+75	28	17	37	23.5	22	34	36.5	24
9+90	29	24	22	27	23	29	12.5	26
6+10	28	26.5	24.5	26	27	5.5	23	16.5
3+45	26	30	33	23	23.5	34	22.5	29
0+0	25	29	28.5	30.5	24	38	38	31

SUMMARY AND CONCLUSIONS

The shoreline erosion analysis has shown that the Weko Beach shoreline has experienced a general trend of erosion until 1974. From 1974 to 1980, the beach stabilized, due to rising lake levels and the jetty at the boat launch ramp and two groins at stations 16+00 and 17+00. Observations during the summer of 1981 indicate a continuation of this stable beach.

The conclusion of this investigation is that the beach between stations 3+45 and 18+90 will remain stable for the forseeable future. The beach house will, therefore, remain unthreatened. It is of critical importance that the existing groins and sheet pile jetty remain in place. Even if Lake Michigan rises to 1973-74 levels, the shoreline structures will protect this reach. The stability of this beach section would be threatened if any major shoreline structures were built between Weko Beach and the Cook Nuclear plant.

The beach area to the south of station 18+90 is unprotected, and may erode further if high lake levels return and coincide with a period of severe storms. However, this erosion will be retarded by the groin at station 17+00±, and should not proceed significantly inland from the 1974 location. This area presently has a large beach, and protective structures are not recommended at this time.

It must be remembered that prediction of shoreline erosion is not an exact science. Therefore, several possible alternative erosion control measures are evaluated in the following section. In the event that unexpected conditions occur on the beach, a low cost, emergency solution may be implemented. At this time, however, the predicted stability of the beach indicates that shoreline protective structures would not be cost effective.

SECTION III - EVALUATION OF SHORELINE EROSION CONTROL MEASURES

DESIGN CRITERIA AT WEKO BEACH

This section presents a review of possible shoreline erosion control plans for Weko Beach. Since financial resources are limited and the beach appears to be stable, emphasis is placed on low cost measures that could be implemented on an emergency basis. Recommendations will be made for the most appropriate system for Weko Beach. This information can be retained for possible future use, if the need for beach protection develops.

The following general design criteria will serve as a basis for the evaluation.

1. It is assumed that existing shoreline structures will remain intact, and that no additional major structures will be built to the north.

2. The area immediately in front of the beach house, approximately 200 feet long, is the only area that might need protection.

3. The water intake and pipeline are currently functioning well. There is no need for additional protection in this area.

4. Some inexpensive measures may be considered for preventing sand from encroaching on the boat ramp.

5. Construction of large shoreline structures are not warranted; City officials and the people of Bridgman do not want large structures, based on financial and aesthetic considerations.

The basic types of shoreline protection under consideration include:

1. Construction of a groin field to trap a protective sand beach.

2. Construction of an offshore breakwater, to shield the shore from waves and trap sand moving along the beach.

3. Beach nourishment to periodically replenish sand eroded away.

4. On-shore reinforcement, such as a stone revetment or seawall.

Onshore reinforcement would dramatically change the appearance and use of the beach in that area. Since this is contrary to the desires of the City officials, onshore reinforcement was not further considered.

Groin fields and offshore breakwaters may be of various types and materials. Several patented systems are available. The following discussion summarizes systems that have been successfully used or that show particular promise for locations such as Weko Beach.

GROIN FIELD ALTERNATIVES

1. Stone Rubble - Rubble groins have been used for years as a durable shore protection device. The structure normally has a core of small stone and rock, capped by an armor stone layer designed to withstand the wave forces at the specific location. The groin may be designed to project any distance (normally perpendicular to the shore) out into the water. The existing groins at Weko Beach are rubble, and have stood up well to wave attack.

   For the Weko Beach area, a groin would be designed to extend 50 feet into the water, to a water depth of 3-4 feet. The armor stone layer would be approximately 1-2 ton stone (3-4 feet in diameter). The cost of such a structure would be about $12,000 - $15,000. In an emergency, a smaller structure, costing proportionately less, would be adequate.

   The major advantages of a rubble mound groin are durability and no maintenance.

2. Timber Crib Groin - Timber cribs, filled with stone rubble, have been effectively used at many locations, as an inexpensive means for shoreline protection. Again, a structure may be custom designed for a specific location. Cost of a 50 ft timber crib groin would be about $5,000. However, the structure would not be as durable as a stone rubble groin and the appearance is not as natural.

3. Steel Sheet Pile - For open lake areas with heavy wave action, a double sheet pile structure, filled with stone or earth fill would be required at a cost of $150 - $200 per foot. Such a structure would provide durable protection comparable to the stone groin, at a similar cost. The appearance may be somewhat less appealing.

4. Longard Tube - The Longard Tube shore protection system has been successfully used in Europe for many years. Made in either 40 in. or 69 in. diameter, the impermeable, flexible, polyethylene tubes are covered with custom woven synthetic fibre. The tube is filled with sand on the site to provide a stable barrier to wave action and/or sand movement. The tubes may be used either as a groin or as a nearshore breakwater parallel to shore.

   At Weko Beach, twin 40 in. Longard Tubes could be installed as a groin, extending about 50 feet from shore. The cost for such a system would be $8,000 - $12,000, including mobilization.

   Longard Tube groins and breakwaters have been successfully used for shore protection along the Great Lakes. The major problems have been settling of the tubes and questionable durability. Debris can tear the tubes, particularly in areas of high wave attack. In several instances, vandals have also destroyed tubes. Since the system is only slightly less costly than a rubble groin, Longard Tubes are not recommended for small projects such as Weko Beach.

5. Permagroin - A patented groin section, manufactured by Permagroin, Inc. of Dania, Florida, consists of a 30 ft long, 6 ft high, 5 ft wide, reinforced concrete structure. The sides are perforated to enhance dissipation of wave energy. Such a structure could be installed at Weko Beach, at a cost of about $10,000.

6. Sand/Concrete Filled Bags - As a low-cost emergency system, sand bags have proven temporarily effective in stopping shoreline erosion. Placed as either a groin or onshore protection, sand bags can reduce wave energy and hold beach material in place. Wave action and debris severely limit the useful life of this system. Therefore, it is not recommended for Weko Beach.

   In an attempt to improve durability, concrete filled bags have been used in place of sand bags. The concrete "blocks" will continue to function after the bag is torn. Again, this system should only be considered as an emergency measure. The cost of such a system would be variable, depending on the site requirements.

OFFSHORE BREAKWATERS

In this context, offshore breakwaters are structures placed parallel to shore at any distance from 20 feet to 200 feet from shore. The breakwater serves two purposes:

1. To shield the threatened shoreline from erosive wave action.

2. To trap sand moving along the shore behind the structure, thereby enhancing the protective beach.

The cost of offshore breakwaters is highly variable, depending on the water depth of the installation. Several types of offshore breakwaters are described below.

1. Stone Rubble - Most offshore breakwaters in water depths greater than 3 feet are made of stone rubble. Successful installations have have been completed at Geneva Park and Lakeview Park, Ohio, and at Presque Isle State Park, Pennsylvania. In each case, the objective was to increase and protect an eroding beach; a similar situation to Weko Beach. As with rubble groins, the breakwaters are built with a core of small rock (6 in. - 12 in.) and capped with armor stone.

   At Weko Beach, a 100 foot long offshore breakwater, located in front of the beach house at station 10+50 to 11+50, in a water depth of

3-4 feet would expand the beach from station 9+50 to station 12+50. One to two ton armor stone would be required. The estimated cost would be $30,000 to $40,000. It is apparent that a rubble offshore breakwater is considerably more expensive than a small groin. Additional protection is provided, but the additional cost is not justified at Weko Beach.

2. Sta-Pods - The Sta-Pod system, consisting of interlocking concrete units with four legs, may be installed in shallow water to protect a reach of shoreline. The system has proven to be quite effective. However, the high cost ($250 per foot) and significant visual impact on the shoreline preclude use of this system at Weko Beach.

3. Miscellaneous Shore Protection units - Several other patented precast concrete units have been used for shore protection. These include surgebreaker, sandgrabber, Z-wall, and Nami Rings. Each is installed on or close to shore, with the purpose of dissipating wave energy and retaining sand. Costs range from $110 to $250 per foot of shoreline protected. None of these systems are appropriate for use at Weko Beach.

SUMMARY OF SHORE PROTECTION SYSTEMS

Table 3 summarizes prior experience with the systems described above. Estimated 1981 cost information is presented, along with comments regarding feasibility at Weko Beach.

BEACH NOURISHMENT

As an alternative to installing protective groins or breakwaters, nourishing the beach by simply adding sand would provide at least temporary protection. Assuming that such a project would extend a 300 foot length of beach 50 feet seaward, (5 ft average depth) a total of 2,800 cubic yards of sand would be required. At an average cost of $3.00 per cubic yard, this nourishment project would cost $8,500 to $9,000

TABLE 3

SUMMARY OF SHORE PROTECTION SYSTEMS

PROTECTION SYSTEM	LOCATION	YEAR INSTL.	LENGTH	COST/FT	1981 COST/FT	FEASIBILITY AT WEKO BEACH
Groins						
Stone rubble	Various	--	--	--	$200	50' groin - good long-term protection
Timber crib	Sanilac, Mi.	1975	<50'	$ 30	$ 50	Technically and economically feasible - 50' groin <$5,000
Double steel sheet pile, filled	Various	--	--	--	$150	Good long-term protection
Longard Tube						
Twin 40"	Sanilac, Mi.	1973	100'	$ 55	$100	Low durability, subject to vandalism, not for high wave locations, consider as emergency measure
Single 69"	Sanilac, Mi.	1973	50'	$ 71	$130	
Permagroin	--	--	--	--	$300	30' long section
Sand filled bags	Slaughter Beach	1979	618'	$ 55	$ 70	Bags lost; short-term solution only
	Sanilac, Mi.	1973	60'	$ 30	$ 55	
Concrete/sand bags	Fountainbleu, La.	1979	?	$ 48	$ 60	Function after bags torn; low cost short-term measure
	Alameda, Ca.	1978	600'	$ 36	$ 50	
Double Sta-Pod			75'	--	$250	Quote, Permagroin, Inc. Cleveland, Ohio
Offshore Breakwaters						
Stone rubble	Various	--	--	--	$300 $1,000	High cost, not necessary at Bridgman
Sta-Pods	Geneva St. Pk., OH.	1978	3' depth	$116	$250	Permeable, limited protection; high cost

Offshore Breakwaters (Con't)		YEAR INSTL.	LENGTH	COST/FT	1981 COST/FT	FEASIBILITY AT WEKO BEACH
Sandgrabber	Basin Bayou , La.	1979	240'	$120	$145	Costly for small job.
Surgebreaker	Basin Bayou, La.	1979	200'	$125	$150	Costly for small job.
Z-Wall	Geneva Park, Oh.	1978	150'	$206	$250	5-6 year life; expensive.
Sand bags	Kitts Hummock, N.C.	1978	336'	$155	$200	Poor durability, short-term measure.
Cement/Sand filled bags	Alameda, Ca.	1978		$ 23	$ 35	Cost highly variable; emergency measure
Nami Rings	Little Girls Pt., Mi.	1974	300'	$ 63	$110	High cost, poor durability

SECTION IV - RECOMMENDATIONS

The conclusion of the shoreline/beach erosion analysis is that the beach has likely reached a state of relative equilibrium. The existing small groins and boat ramp jetty prevent more sand from eroding from the area in front of the beach house. The beach south of the groins may erode slightly, but not enough to seriously affect use of the area. The two groins also provide adequate protection for the water pipeline.

Based on these findings, the recommended approach for Weko Beach is to take no action at this time. In the unlikely event that unexpected conditions, either increased shoreline construction to the north or extremely severe storms combined with record high lake levels, occur then measures may be taken to protect the facilities. It would not be cost effective to construct protective works at this time.

Based on our evaluation of available erosion control options, the following "contingency" plan has been developed. If needed, a single rubble mound groin, extending approximately 50 feet into Lake Michigan would trap sand on the north side and provide protection for the beach house. The location of this groin is shown on Figure 4. The estimated cost is $15,000 (1981 dollars), including mobilization and miscellaneous costs and fees. Alternative construction materials for the groin are shown on the figure for comparison. The superior durability, natural appearance, and no maintenance justify the slight additional cost for the rubble structure.

It is also suggested that an attempt be made to build up the jetty on the north side of the boat ramp. Since the few rocks to the south of the ramp are of no value at that location, efforts could be made to move those to the north side. The effectiveness of the north jetty would be improved by increasing the height by 4-6 feet.

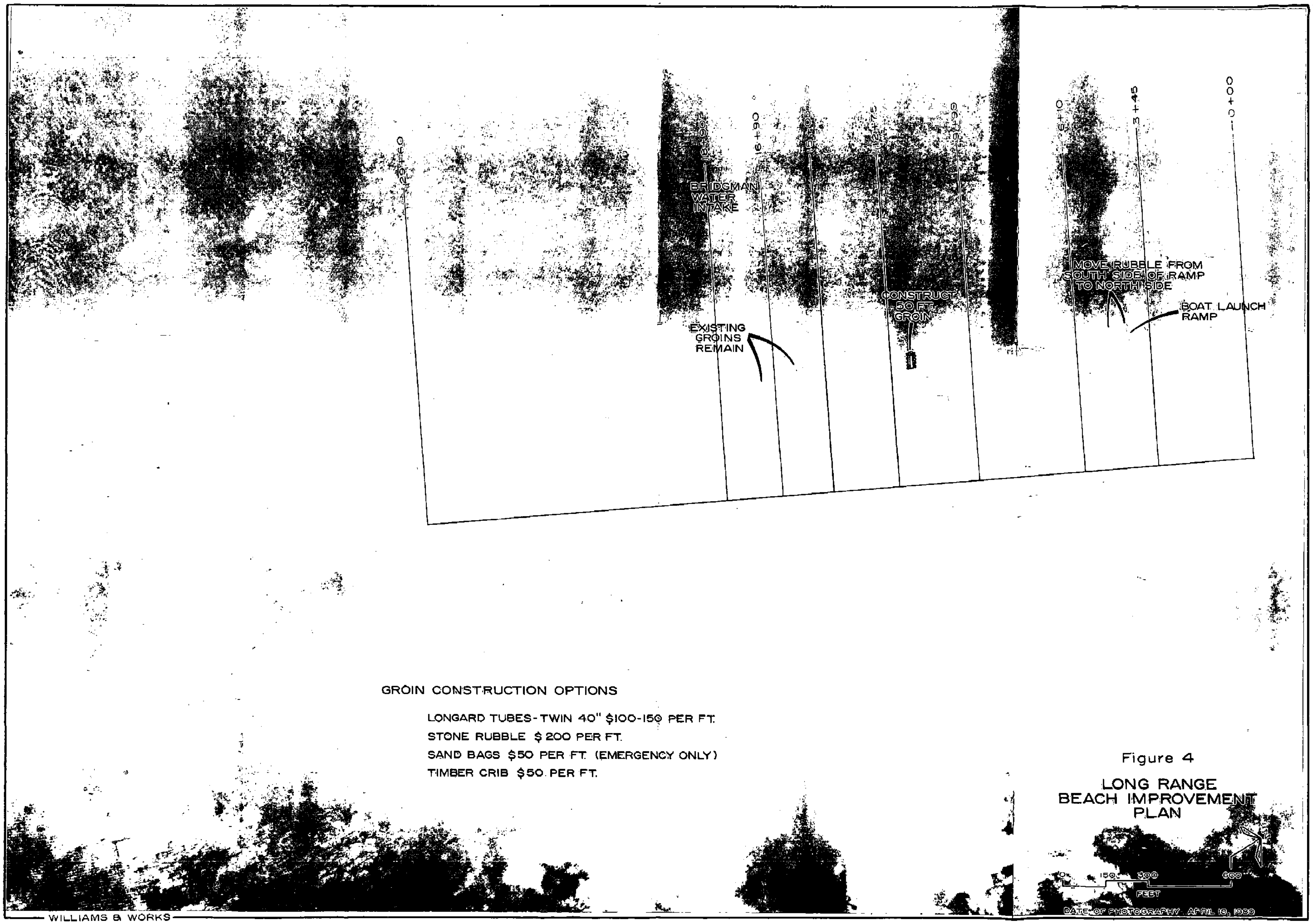

Figure 4

LONG RANGE BEACH IMPROVEMENT PLAN

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