REPORT ON

RIVER BANK PROTECTION STUDY

WAPELLO, IOWA

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INTERNATIONAL CONSULTANTS IN ENGINEERING, ARCHITECTURE, PLANNING, AND MANAGEMENT

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January 23, 1975

Iowa Conservation Commission
State Office Building
300 Fourth Street
Des Moines, Iowa 50319

Gentlemen:

Re: Report on River Bank Protection Study
Wapello, Iowa

We are pleased to present the results of our investigations at Wapello. This work was undertaken under Agreement No. 74-20 in response to the legislative resolution concerning erosion problems at Wapello.

Respectfully submitted,

STANLEY CONSULTANTS, INC.

W R Klatt

W. R. Klatt
Vice President

REPORT ON

RIVER BANK PROTECTION STUDY

WAPELLO, IOWA

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SYNOPSIS

Steadily advancing bank erosion of the Iowa River at Wapello threatens eventual destruction of an important part of the town and has been of increasing concern for more than thirty years.

In May, 1974, the state legislative council requested the Iowa Conservation Commission to study and report on the situation. At the beginning of Iowa's new fiscal year in July, the Conservation Commission employed Stanley Consultants, Inc. to undertake this work.

Relevant factors investigated include river stage/frequency, velocity, historical channel changes, cross section surveys, sediment load and characteristics, nature and structural properties of principal soils types, groundwater levels and gradients, the mechanics and cause of bank failure at Wapello, possible erosion protection plans, environmental aspects and possibilities for development of the project as a public asset.

River levels were found to fluctuate within the zone of most resistant bank materials over 90 percent of the time. During passage of floods, less resistant overlying sand materials are exposed to the possibility of erosional attack. Failure seldom, if ever, is reported to occur at such times. Existing moderately dense vegetation is apparently well able to resist erosion from the swift flowing flood waters.

River velocities are high and greatest near the Wapello bank where current meter gagings have measured point velocities in excess of 9 feet per second during floods. This is sufficient to cause erosion of all the materials exposed in the river channel at Wapello.

Comparison between aerial photographs taken in 1941 with those taken in 1969 shows that extensive river channel changes, reaching a maximum of about 400 feet, have occurred near Wapello in the intervening period. Erosion of the river bank through Wapello is much less and is estimated to have been about 12 feet during the same period. Resistance to rapid erosion of Wapello's river bank is credited to a tough clay layer found beneath the upper sand layer against which most of the erosive forces are directed. This clay zone is absent at locations where extensive channel changes have been experienced. Although the rate of erosion is slow at

Wapello, the river's angle of approach assures continuance of the erosion process for a very long period. No natural phenomenon has been found that will arrest its progress.

We have concluded that erosion of the river bank at Wapello is naturally controlled by the rate at which flowing sand laden water, flowing ice, and weathering is able to wear away the tough clay material underlying the upper sands. The more obvious slides which occur from time to time in the upper sand zone take place after the underlying clay has been eroded to the extent that the sand slope becomes unstable. Because of the high cohesive strength of the tough clay, slope slides seldom, if ever, penetrate the clay zone.

The study included investigation of seepage forces due to internal flowing groundwater. Seepage forces were initially considered to be a likely cause of bank failure, but were found to be insignificant in causing a slide near Jackson Street which occurred during our study. The medium sand layer found beneath the clay zone may be exposed at one particularly deep point of the river channel. This layer had piezometric gradients of about .002, insufficient to cause quicksand conditions as water escapes vertically through the sand into the river. However, more adverse seepage pressures could be present under more extreme climatic and river level fluctuations. This possibility has been considered in preliminary design of the recommended project.

The recommended plan provides for a mile-long riprap stone revetment protecting primarily the tough clay zone exposed on the river bank and bed on the west bank of the Iowa River at Wapello. A walkway along the revetment about 20 feet below the top of the existing high bank will provide a public benefit that will not affect the privacy of adjacent property. The sand zone above the revetment will be permitted to stabilize with increased vegetation protection. Additional plantings and maintenance will halt recession of the existing slope. Preservation of the natural riverbank is of prime importance to the plan. The estimated total project cost of the revetment wall and walkway is $1,946,100. Enhancement and beautification of the upper slope will be the responsibility of land owners, perhaps assisted by interested civic groups.

The estimated 7.5 million tons annual sediment load of the Iowa River at Wapello will be affected negligibly, both during construction and following project completion. During construction turbidity will locally increase by disturbance of bottom deposits. Elimination of bank erosion through Wapello will bring about a slight improvement in water quality upon completion of the revetment. Preservation of the existing alignment will ensure that no factors will be introduced likely to change existing river currents and sediment bar patterns to any predictable extent and no adverse effect on the channel is anticipated. Minor channel encroachment from the revetment will be speedily offset by erosion of the cross section. It is estimated that this compensating erosion will be from deposits near the far river bank rather than the channel bed. Resultant effect, flooding will be negligible.

Temporary adverse effect upon fish and wildlife from construction activities will be insignificant. There is abundant nearby aquatic and terrestrial habitat. The project will enhance the river bank for public enjoyment, enrich the cover and food for wildlife and encourage further beautification of the bank. Public recreation and educational possibilities can be developed.

The recommended project will assure protection of a thin line of property presently under threat and of an appreciable commercial area that would eventually be destroyed. Public recreation, educational opportunities and riverbank beautification will be additional benefits of the plan to halt the steady progress of riverbank erosion.

PART I

INTRODUCTION

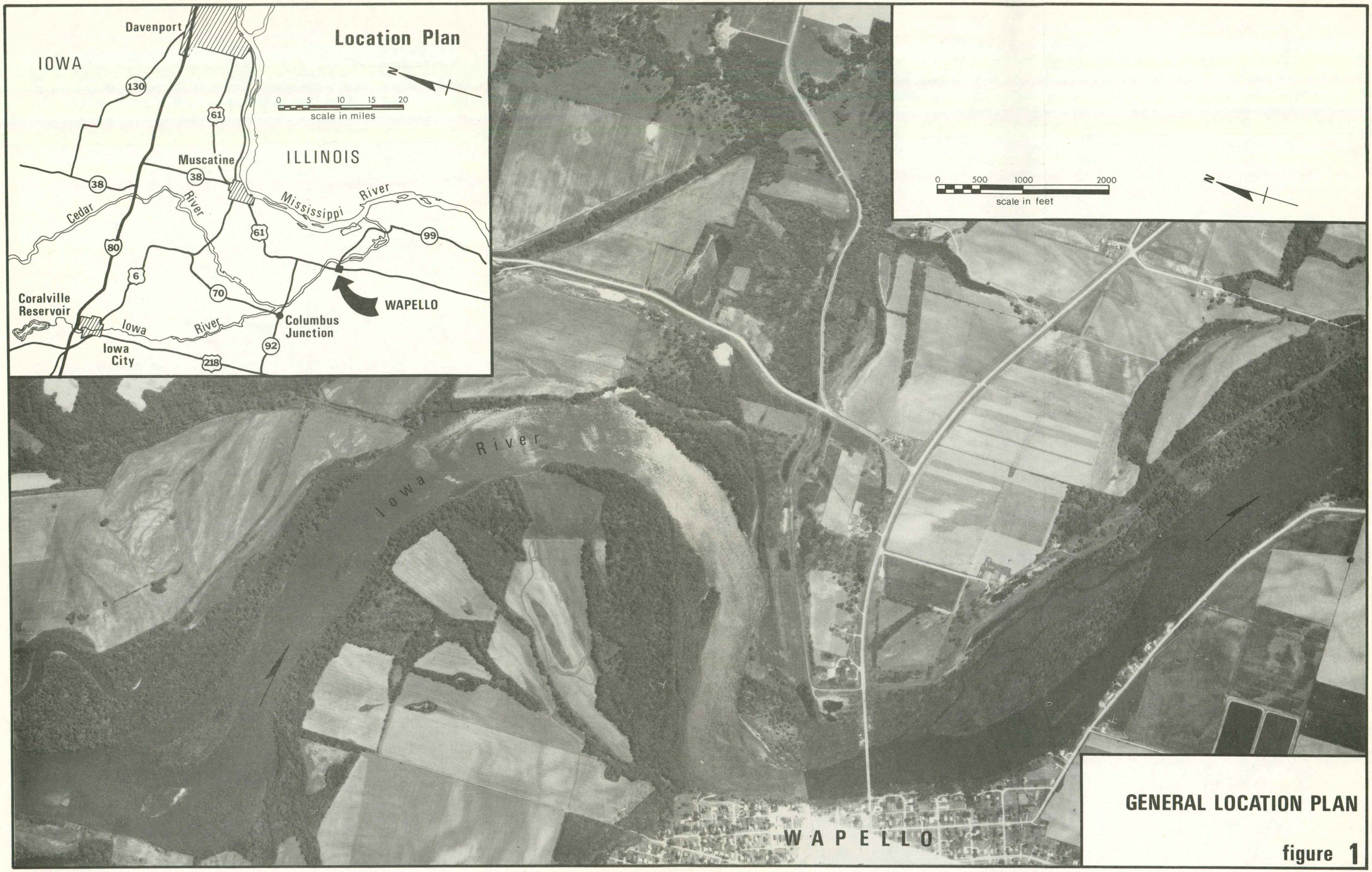
General

The town of Wapello lies on the west bank of the Iowa River in Louisa County, southeast Iowa, and about 13 miles downstream of the confluence of the Cedar and Iowa River at Columbus Junction. The inset map on Figure 1 shows the location of Wapello in eastern Iowa. The aerial photo shows the configuration of the river channel in the immediate study area.

The Iowa River drains about 12,500 square miles above Wapello of which about five-eighths comprises the Cedar River basin. About one quarter of the catchment above Wapello is regulated by Coralville flood control reservoir constructed in 1958 on the Iowa River, upstream of its confluence with the Cedar. United States Department of the Interior, Geological Survey, Water Resources Division operates a river gaging station at Wapello. In cooperation with the Corps of Engineers, USGS personnel perform regular discharge and water quality measurements but have made no river bed load measurements to date.

The average gradient of the Iowa River below its confluence with the Cedar River at Wapello is about 1.43 feet per mile. The heavy sand load carried by the Cedar River results in visible sand bars distributed along the stream which are a prominent feature under low flow conditions. Sand bars are visible in the aerial photograph on Figure 1 which shows the meandering nature of the stream in the vicinity of Wapello. Also visible in the photograph is strong evidence of marked erosion activity on the outside of river bends and accompanying deposition of sandy material on the inside of bends.

Wapello itself is situated on the outside of such a bend. The riverbank here is subjected to direct erosive attack and resultant property loss. The purpose of this report is to investigate engineering solutions to the problem of riverbank instability at Wapello and determine resulting effects on the environment. The study was initiated by requests submitted to the Iowa Conservation Commission under its jurisdiction "over the bed and banks of meandering streams" followed by a state legislative interim committee directive for the Commission to conduct an investigation. This present study



GENERAL LOCATION PLAN

figure 1

and report has been made under the authorization of the Iowa Conservation Commission.

Previous Investigations

The U.S. Army Corps of Engineers has been interested in the problem of riverbank erosion at Wapello since 1948. At that time and on numerous occasions since then, in response to requests from the City council and concerned individuals they have inspected and reported on bank erosion condition at Wapello. Formerly a navigable stream, the Iowa river was declared not navigable by act of Congress, August 18, 1854.

Within the limitation of no direct fund allocation for the work, the Corps offered as much assistance and advice as they could short of carrying on a detailed study, which they were not authorized to undertake. Their assistance culminated in production of a preliminary design for bank erosion protection at Wapello. This plan was not very different from the recommended plan submitted in this report.

The Corps of Engineers at Rock Island have been kind enough to review the basic findings of this report and have offered suggestions for a possible variant of a construction detail which will be investigated in final design.

History of Erosion Loss

The story of riverbank erosion in the vicinity of Wapello is graphically portrayed in the series of aerial photographs regularly flown for the Department of Agriculture. Figure 2 shows comparative channel alignments illustrating channel changes over the 28-year period from July 1941 to May 1969. Bank erosion up to about 400 feet in certain areas is apparent. The extent of erosion through the town of Wapello is less dramatic. About 12 feet of erosion is estimated at the north end of the town, and a low lying area south of town has vanished. Considerable change in flow pattern past islands downstream of the bridge is evidenced.

Erosion of Wapello's high river bank is apparently at a slow rate averaging not more than approximately 1 foot every 2 years. Erosion is nevertheless relentless in its onward progress. Water Street, the road along the riverbank downstream of the bridge in Figure 1 once ran the entire length of the city. It is reported that a ball park formerly

HISTORIC TREND OF BANK EROSION

figure 2

existed to the east of Water Street. Buildings fronting the main business street in town extend to within 180 feet of the edge of the riverbank. In view of the magnitude of erosion demonstrated in Figure 2, these commercial establishments cannot be considered immune from erosion attack in the distant future if protective measures are not introduced. Several residences in the area of Merchant Street are within inches of the bank slope and must be considered as potential losses unless preventive measures are taken.

Nature of the Problem

Riverbank changes commonly are associated with one or more of the following:

1. Channel realignment following bank overtopping during a large flood.
2. Erosive current action associated with natural meandering or with man-made structures introduced into the river channel.
3. General land subsidence caused by earthquakes, fault zones or weak foundation materials.
4. Cross section changes caused by special geological conditions, changes in river sediment load or discharge, unstable side slopes, weathering or fast currents.

The high riverbank at Wapello protects the town from marked channel changes resulting from overflowing flood waters. Strong earth movements from earthquakes or fault zone slides are also not characteristic of the area nor have they been reported as associated with past bank slides. The other factors mentioned above, however, are all present to varying degree. The importance and interdependance of these factors and methods of nullifying their effects are the object of this study.

Figure 3 shows a recent river bank failure just upstream of the bridge. It appears typical of similar slides, evidences of which may be seen at numerous places along the bank. Figure 3 illustrates a local failure in which a wedge about 10 feet wide is seen to be slowly sliding into the river. The sliding surface of undisturbed soil on the landward side of the subsidence is almost vertical. The direction of movement of the sliding wedge is about vertical as evidenced by trees growing vertically in the disturbed zones.

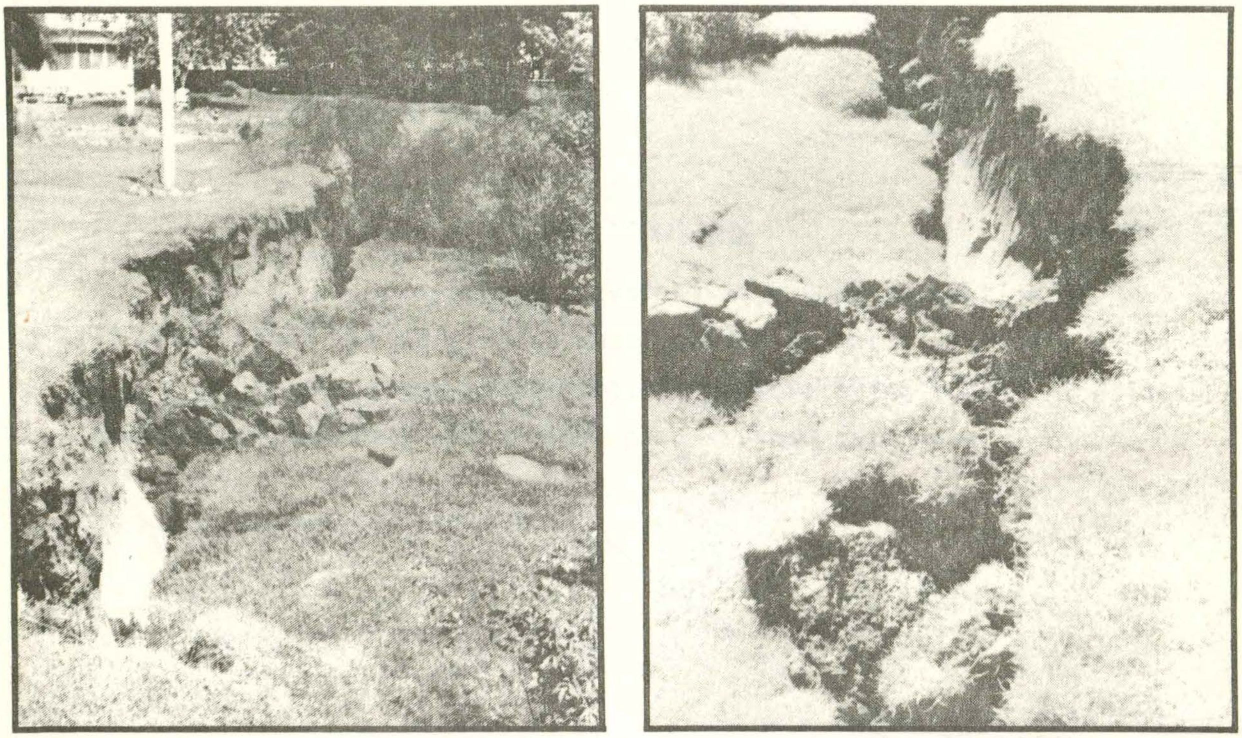


FIGURE 3

SLOPE FAILURE, WAPELLO, JULY 1974

This is apparently a typical "slope failure" of an embankment. It occurred in late July of this year after river levels and high flood velocities of spring runoff had fallen. Slope failures occur when bank materials have insufficient strength to withstand the sliding forces naturally imposed upon them. The sliding plane in such failures is always above the bottom toe of the bank.

portion of the bank itself is a more evident cause of failure than is rapid water velocity, which might be expected to have its most devastating effect in times of flood when river currents are high.

The process of slope failure described above as being an important factor in the problem at Wapello, is one which frequently operates in nature for the stabilization of over-steep slopes. Buildup of slumped material at the toe of an unstable slope has the effect of making the resultant surface less steep and ultimately results in a stable slope where no further slides occur.

The fast-flowing river at the foot of the riverbank slope is capable of transporting the type of material which likely to slide at Wapello, thus preventing the natural stabilization process. There appears to be no natural factor present capable of preventing erosion on the outside of the Wapello river bend. A large area of Wapello, including the commercial area of Second Street to the north of Franklin Street, is under threat of ultimate erosion by the river if no preventative action is taken.

Figure 3 is typical of bank failures through the town which rarely result in complete subsidence of the sliding wedge into the river but more commonly in a drop of a few feet. It has been common practice in Wapello to attempt to remedy the situation by dumping fill material on top of the subsided wedge thus restoring the original bank profile. Not surprisingly, this has usually been of short duration. The weight of added materials soon causes a fresh slide and the need for more dumping. This practice, although inefficient in its use of materials, can ultimately result in a partial solution to the problem. If added materials are capable of withstanding high river currents, repeated dumping will ultimately result in complete replacement of the original wedge. In the process of dumping, the added materials will naturally assume a stable side slope. This course of action involves uneconomic use of materials, destroys the attractive vegetation which lines the upper bank, provides a piecemeal solution leaving many intermediate unprotected areas and has resulted in the dumping of unsightly materials on the river bank.

Soils investigations described in the next section of the report reveal the reason for the slow rate of erosion at Wapello and make possible the preliminary design and evaluation of several proposed protection works discussed later in the report.

Acknowledgments

The interest and assistance of the Corps of Engineers, Rock Island District, is appreciated as is that of Mr. S. W. Wiitala, District Chief, U.S. Geological Survey and Mr. O. R. McMurry, Director of Iowa Natural Resources Council is acknowledged with appreciation.

PART II

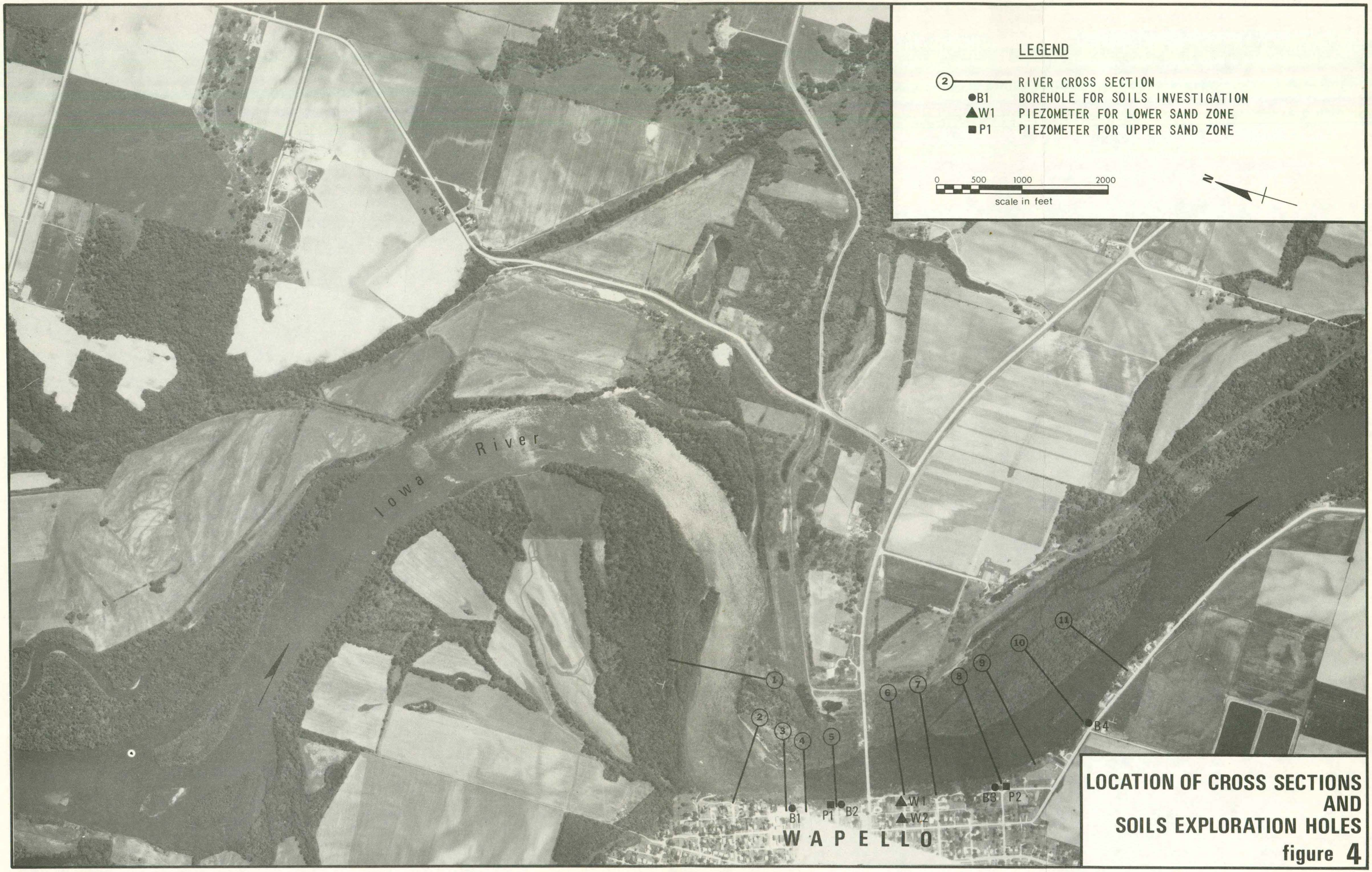
INVESTIGATIONS AND ANALYSIS

Soils Exploration

Prior to initiation of this study, it was generally known that Wapello is underlain by three principal soils types relevant to this study. These were described as an upper water bearing sand, a clay layer, and an underlying layer of "sugar sand." This latter, is the source of Wapello's well water supply. Quicksand properties have been ascribed to this lower zone necessitating its study in this report. The clay layer was also suspect. Some soft clays have very little shear strength and cannot support bank heights present at Wapello. The nature of the upper zone of sand will determine the stable side slope in this zone. A program of drilling, sampling, logging and testing of these principal zones was undertaken to evaluate these factors.

The firm of Soil Testing Services of Iowa, Inc. was selected to perform this soils testing work. A program of minimum reasonable soils exploration was arrived at in cooperation with and under the direction of Stanley Consultants. Soil Testing Services of Iowa, Inc. were to drill, sample, classify and log four boreholes extending well below the bottom of the river into the lower sand zone. They were to perform tests sufficient to establish the structural strength of each principal zone, analyze the stability of existing side slopes and describe measures for bank stabilization. Their principal recommendations together with recommendations which have been proposed from time to time by others have been further developed and are discussed in detail under the protection plans analyzed in this report. Copies of drilling logs are included as Appendix A to this report. Figure 4 shows the location of the boreholes.

Early concern over possible quicksand action of the lower sand zone necessitated investigation of piezometric levels and gradients in this zone. Two 2-inch wells were constructed. These were driven through the clay zone and cleaned out by means of a small rotary bit. A 5-foot length of 10-slot screen extended into the lower sand zone and the well was developed by pumping at the rate of several gallons per minute. These two piezometers were constructed in Washington Street approximately perpendicular

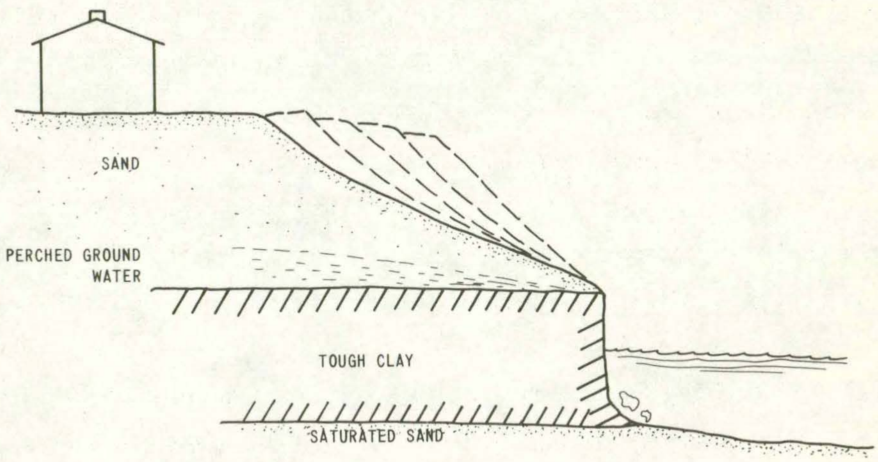


LOCATION OF CROSS SECTIONS AND SOILS EXPLORATION HOLES

figure 4

to the direction of the river at approximately 90 feet and 267 feet, respectively, from the edge of the riverbank.

Construction of these two piezometers (W-1 and W-2 on Figure 4) was completed in July 1974 and water levels have been recorded from July 30. At this time and during the period of record, river levels have been slowly subsiding. During the period, piezometric levels within the lower sand zone have been within 0.5 feet of river level at the further piezometer and show a gentle gradient (not exceeding .002) towards the river. Rainfall has been low during the period but little likelihood of strong flows within this sand zone, under normal conditions, is apparent. The possibility that failure in the upper sand zone might also be the result of perched ground water was next investigated.



SLOPE FAILURE IN UPPER SAND ZONE
(TOUGH CLAY RESISTS SLIDING FAILURE)

Two additional piezometers (P-1 and P-2 on Figure 4) were constructed in the upper sand zone and extended down to the surface of the clay layer. Since construction, these have been virtually "dry holes." No appreciable water flow in the upper sands has been apparent since July of this year although some local failure close to P-1 has been experienced. There is little evidence of springs along the junction plane of the upper sand and the clay zone. One small spring was found at the boat launching ramp at Vernon Street about 1,000 feet downstream of the bridge. Water flow at this location was very small.

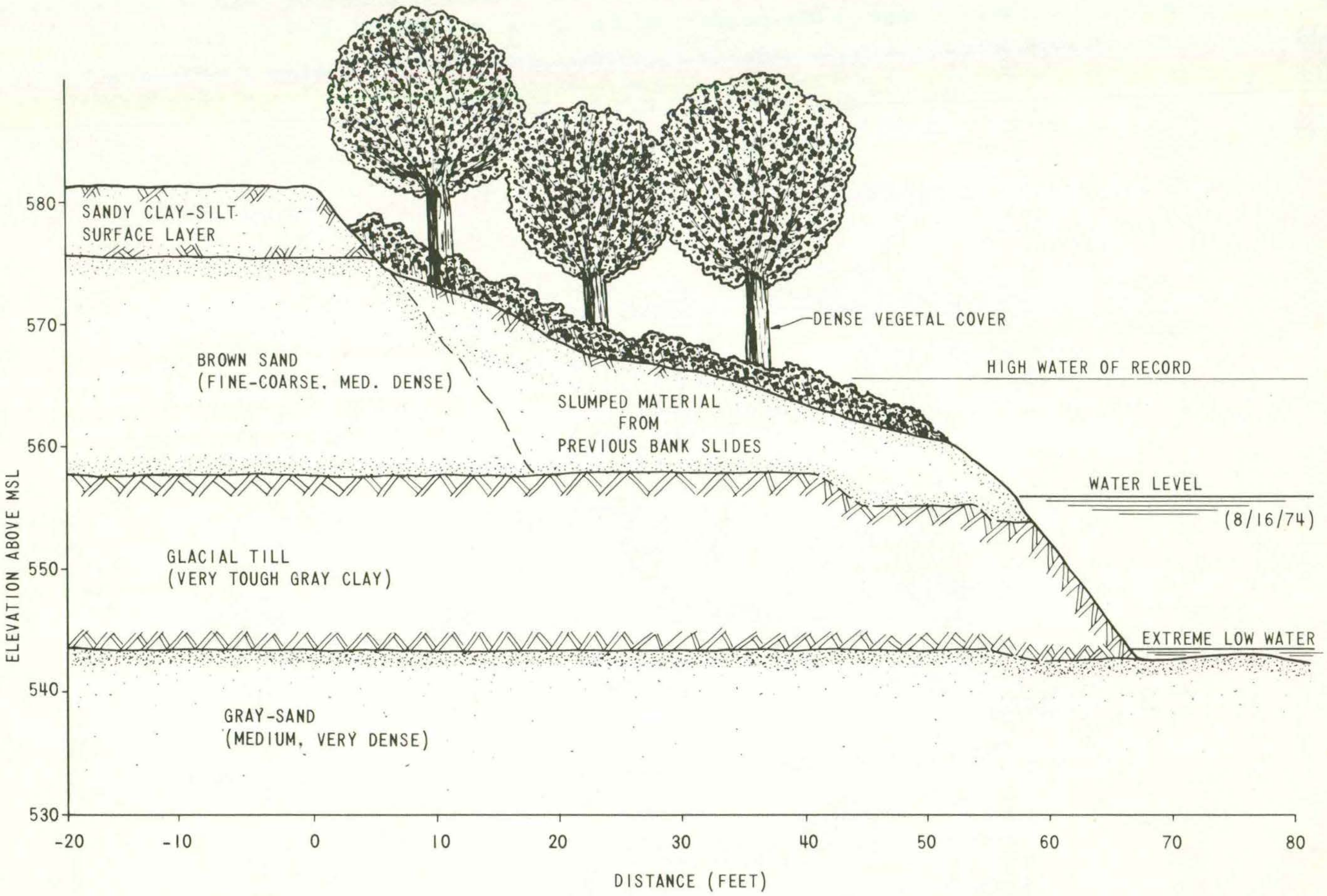
The period of investigations for this study was unusually dry. It is possible that steep hydraulic gradients are present within both aquifers - particularly under "rapid drawdown" conditions associated with falling river stage. Rapid drawdown of 4 feet of water has been provided for in the structural design of proposed remedial measures.

A most significant fact is that slippage has been experienced along the riverbank upstream of the bridge during this same period when the factor of water seepage pressures has not been present.

River cross sections were surveyed at the locations shown on Figure 4. These have enabled us to analyze the stability of the existing riverbank, compute quantities of materials required for stabilization construction and estimate the effects of this construction on flood stage and river sediment transport.

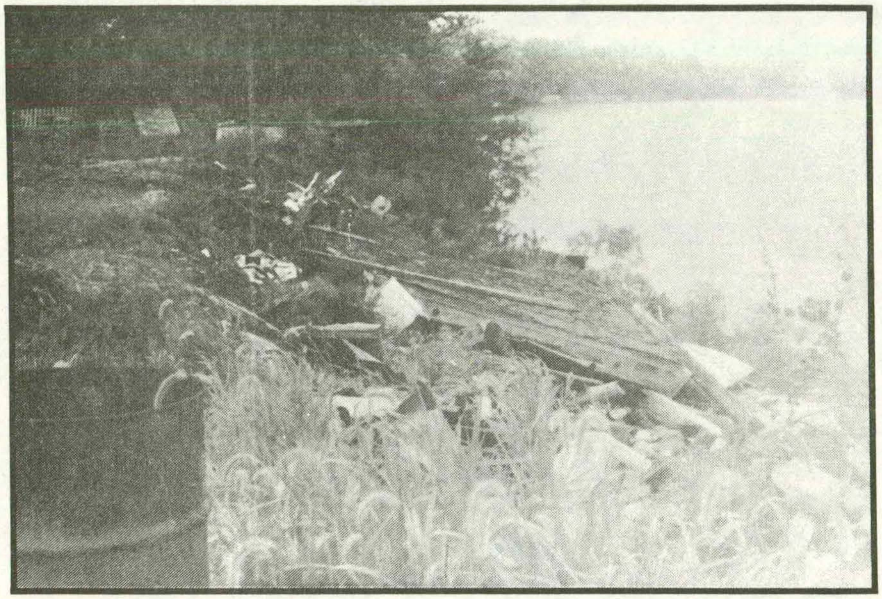
The boreholes reveal a marked uniformity in depths of these principal soil types over the study area. Figure 5 shows the depths at which these formations are found drawn upon a portion of surveyed river cross section. The cross section selected was at the deepest point of the river and indicates the lower sand zone exposed on the riverbed. This is the only point where this is known to occur. At other locations the lower sand zone is probably covered by a few feet of clay in the bed of the river. This may be obscured by the moving sand bed-load present in the river. The bed load sand appears to be appreciably coarser than the lower medium sand and is expected to form a filter blanket above any exposed areas of medium sand thus providing natural protection against quicksand formation. The upper sand zone is subjected to river water attack during high floods. The abundant cover of vegetation is apparently sufficient to prevent severe erosion at such times.

Because of the great importance of each soils type in relation to understanding the problem at Wapello, each type will be described in greater detail.



TYPICAL RIVER BANK SECTION

figure 5



TYPICAL RIVER BANK, WAPELLO, IOWA

Soils Characteristics

The strength of a soil against the type of failure resulting in bank slides is derived from two factors. Frictional resistance against motion of one particle against another increases as the pressure between particles increases. Fine-grained materials like silt and clay develop additional strength by a cohesive force which, in soils, is usually due to the action of moisture films. This cohesive force resists sliding motion of the soil.

The ability of an uncohesive soil to withstand erosion by moving water depends upon particle size and density coupled with friction, side slope, and velocity and depth of water. Fine-grained, noncohesive sands are easily moved by flowing water. Coarser-grained gravel and rock are able to withstand higher velocities as the diameter of the individual particle increases. Cohesive soils, though comprised of very small particles, show a marked apparent resistance to erosion by flowing water. The same forces which give added strength to cohesive soils to resist bank slides also resist erosion of particles by flowing water. Erosion is resisted but may continue at a very slow rate. Side slopes of cohesive materials may appear stable because no dramatic movements are evident. Erosion of individual particles, however, will steadily continue, brought about by "sand blasting" of sediment laden water and by drifting ice and the thrust of a solid river ice. This process may be accelerated at Wapello by weathering. The action of freezing upon a saturated cohesive material frequently breaks down a thin surface film which may be easily eroded by subsequent flowing water.

The Upper Sand Zone

The upper sand zone may be subdivided into two layers. The upper 13 feet consists of silty fine to medium sand of loose to medium density underlain by 10 feet of fine to coarse sand of medium density. Generally, the median particle size of this layer is 0.39 mm. Cohesion is very small and may be neglected. This material would, in a dry state, stand at stable angle of a little over 30 degrees. There are numerous locations along the riverfront where actual bank slopes are as high as 40 degrees. Slopes in excess of the natural angle of repose exist because of the rich vegetation present which provides roots to further strengthen the soil and cover to protect it against rain and flowing water.

The Clay Zone

This is not a pure clay but contains a high percentage of silt and sand. The result is a tough material having high cohesion but relatively low friction. A conservative value of 1,500 pounds per square foot of cohesion has been adopted for this zone although individual tests have indicated twice this value. Friction has been neglected in considering the shear strength of this layer. The thickness of the clay layer averages 17 feet.

Because of the high cohesion of the clay zone, slope failure of wedges extending through this zone is improbable. If the clay zone were not subject to erosion by weathering and flowing water, the riverbank at Wapello would stabilize with a nearly vertical clay face overlain by a sand zone sloping back at an angle of approximately 1 on 2.

Progressive recession of the high bank at Wapello is clear evidence that erosion of the clay zone is in fact taking place. The rate of recession is in fact limited by the rate of erosion of the clay zone.

The Lower Sand Zone

This is a medium sand of medium density having a uniformity coefficient of 1.9 and a median particle size of about 0.335 mm. Critical tractive force analysis indicates that this sand, in common with sands commonly found in the bed of the Iowa and Cedar Rivers, is not stable but is in a state of constant bed load movement. As there will be an abundant supply to replace the small amount of lower zone sand exposed at Wapello, the formation of a deep erosion hole is unlikely. Some erosion of the existing bed is to be expected during flood periods. We estimate that this will be about 3.6 feet.

Up to 6 feet of scour has been anticipated in the design of toe apron for the revetment recommended in this report. This extra allowance has been added because of the directness of attack of the river against the right bank which is to be protected.

Longitudinal sonic profiling performed along the river channel in late July gave no evidence of dune formation in the bed material. This does not mean that dunes may not be formed at other times of the year. It may be assumed, however, that any such dune formation is destroyed during the flood season. Seepage pressures in the lower sand measured during the course of our investigations indicate that the "quicksand" conditions, necessitating high hydraulic gradient, were not present. Remedial measures which will be proposed to control the erosion problem at Wapello provide for a filtered blanket of coarse material over exposed lower sand materials where present. This will have the effect of further reducing "exit" gradients and provide safety against sand boils should they tend to occur under extreme conditions not encountered during our study.

Erosion and Aggradation

Investigations for this report led to the discovery that there are indications that flood stages at Wapello are showing a rising trend for a given discharge. Aggradation or building up of the riverbed by sediment deposits between Wapello and the Mississippi River is suspected. Its presence may be due to a reduction in flushing action by flood peak reduction from Coralville dam combined with a backwater effect from higher Mississippi River levels which are presently maintained to assist navigation. The influence of these Federal projects upon the problem at Wapello together with public benefits arising from the recommended plan is considered grounds for requesting Federal aid in supporting a portion of the total cost of the project.

The meandering nature of the stream channel, sure evidence of bank erosion, together with the nature of the sand visible on the bed of the river indicate a heavy sediment load, particularly during floods. The bank revetment for Wapello recommended in this report, by slightly reducing riverbank erosion will lessen the rate of aggradation downstream to a very small extent. Since the riverbed is in a state of near dynamic equilibrium under existing flows and sediment load any encroachment into the river channel by remedial works will be rapidly compensated for by erosion of the remaining section. Resistance to erosion on the west bank will result in compensating lessening of deposition on the east bank.

PART III

PROTECTION PLANS

General

More thorough understanding of the mechanism of bank erosion at Wapello provided by this study provides a basis for critical review and development of various possible preventative measures which have been suggested. Measurements which have been made are sufficient for reasonable estimates of the degree of protection required, the quantity of materials necessary and hence the estimated cost of alternative proposals.

It should be recognized that conditions are not stable along the riverbank at Wapello. Some change is to be expected before any major construction is expected to begin. It is not considered probable that the magnitude of such change will be sufficient to alter selection of the most attractive solution or materially effect quantity estimates upon which preliminary cost estimates have been based.

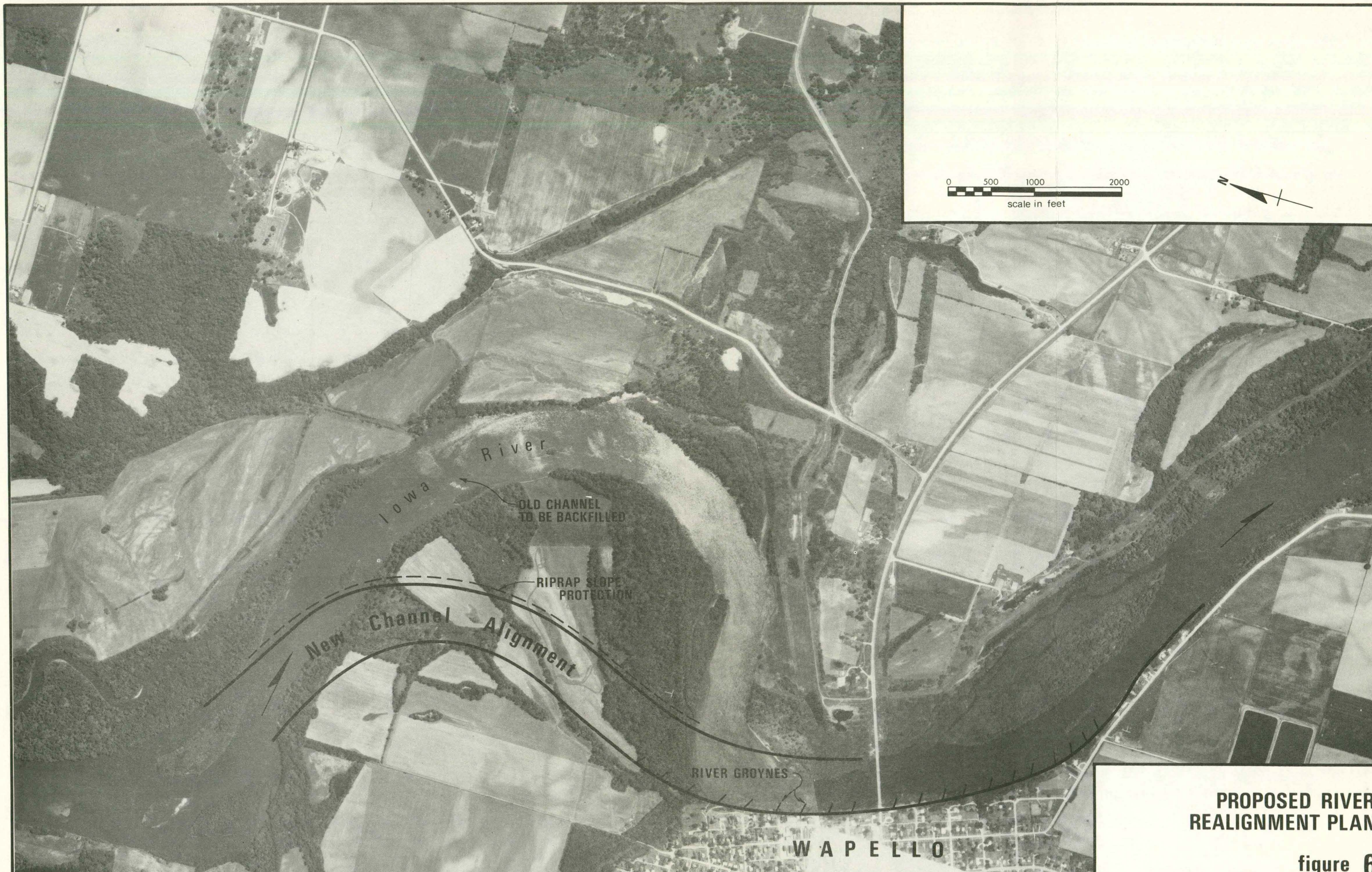
Typical proposals for possible protective measures will be discussed individually leading to presentation of the plan recommended by this study.

Channel Straightening

Because the affected riverbank at Wapello is on the outside of a bend and is consequently subjected to strong erosive attack, one of the most long standing proposals for alleviating the situation has been upstream channel straightening.

Such a plan is presented in Figure 6. The alignment shown represents a compromise short of the possible straight line cut-off which would involve more expensive excavation and loss of agricultural land. It is estimated that 2.9 million cubic yards of excavation would be required for the alignment shown on Figure 6. This material would be placed in the cut-off channel. An additional 2.9 million cubic yards of fill would be required to complete backfill of this channel.

Channel straightening of a meandering stream is invariably opposed by the natural forces present. In this case a shortening of the channel would result in increased slope and sediment transport capacity within the



PROPOSED RIVER REALIGNMENT PLAN

figure 6

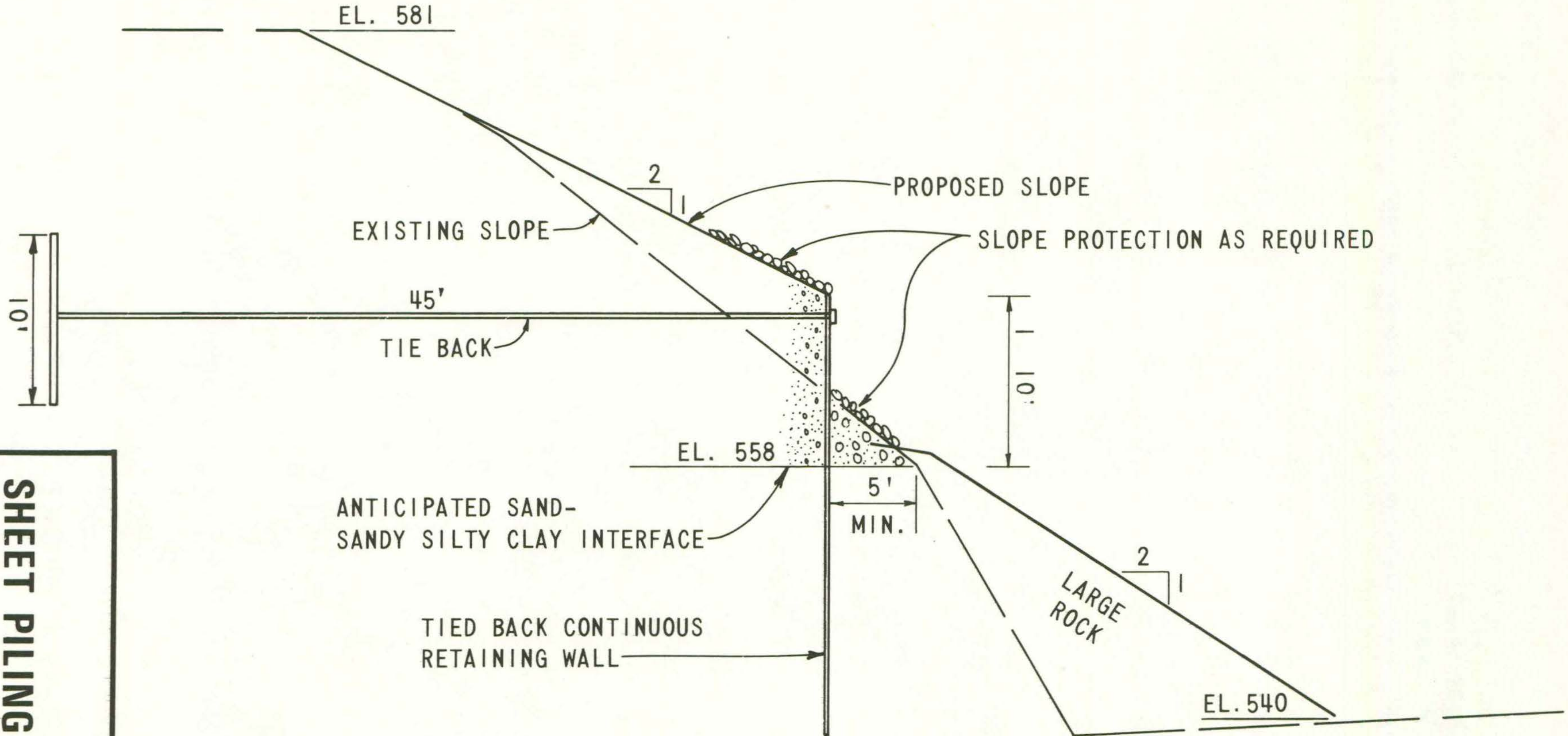
straightened reach. Consequently, erosion of the new channel alignment would be expected and require protective revetment - particularly on the outer side slope. Ample toe protection of this revetment would be mandatory because of the probability of bed erosion. Cut-offs frequently tend to change the existing sequence of pools and bars in a stream. Downstream effects are not always predictable and additional downstream protection may be required to stabilize the downstream channel at critical locations.

Most important is the simple fact that channel straightening would not eliminate bank failure at Wapello. There is abundant evidence of recent riverbank failure at the end of Washington Street (the first street perpendicular to the river downstream of the bridge). Since this is at a point where the river channel is straight, and flow tends to be held straight by vane action of the bridge piers and is not likely to be adversely influenced by secondary currents from upstream meanders we have little reason to suppose that complete protection of the riverbank through Wapello could be accomplished without provision of bank protection through the town in addition to upstream channel straightening.

Since the same effect may be achieved at far less cost with the elimination of upstream channel straightening, this plan is not recommended. The Fisheries Section of Iowa Conservation Commission oppose this channel straightening plan but agree with the plan recommended in this report. Cost estimate for the total contract of a plan involving channel straightening and downstream bank protection is $7,500,000.

Retaining Wall for Upper Sand

Figure 7 shows a type of protection which may be used in two different ways. It consists of a raprap revetment to prevent erosion of the tough clay zone and sheet piling driven into the clay to provide additional support to the weaker overlying sand zone. The cost of sheet piling of this nature, if used to protect the entire length of riverfront of the town, is prohibitively high when it is realized that this degree of protection is not necessary except in a few isolated locations along the river where imminent destruction of structures close to the riverbank is feared. This protection plan is not recommended.



SHEET PILING RETAINING WALL

figure 7

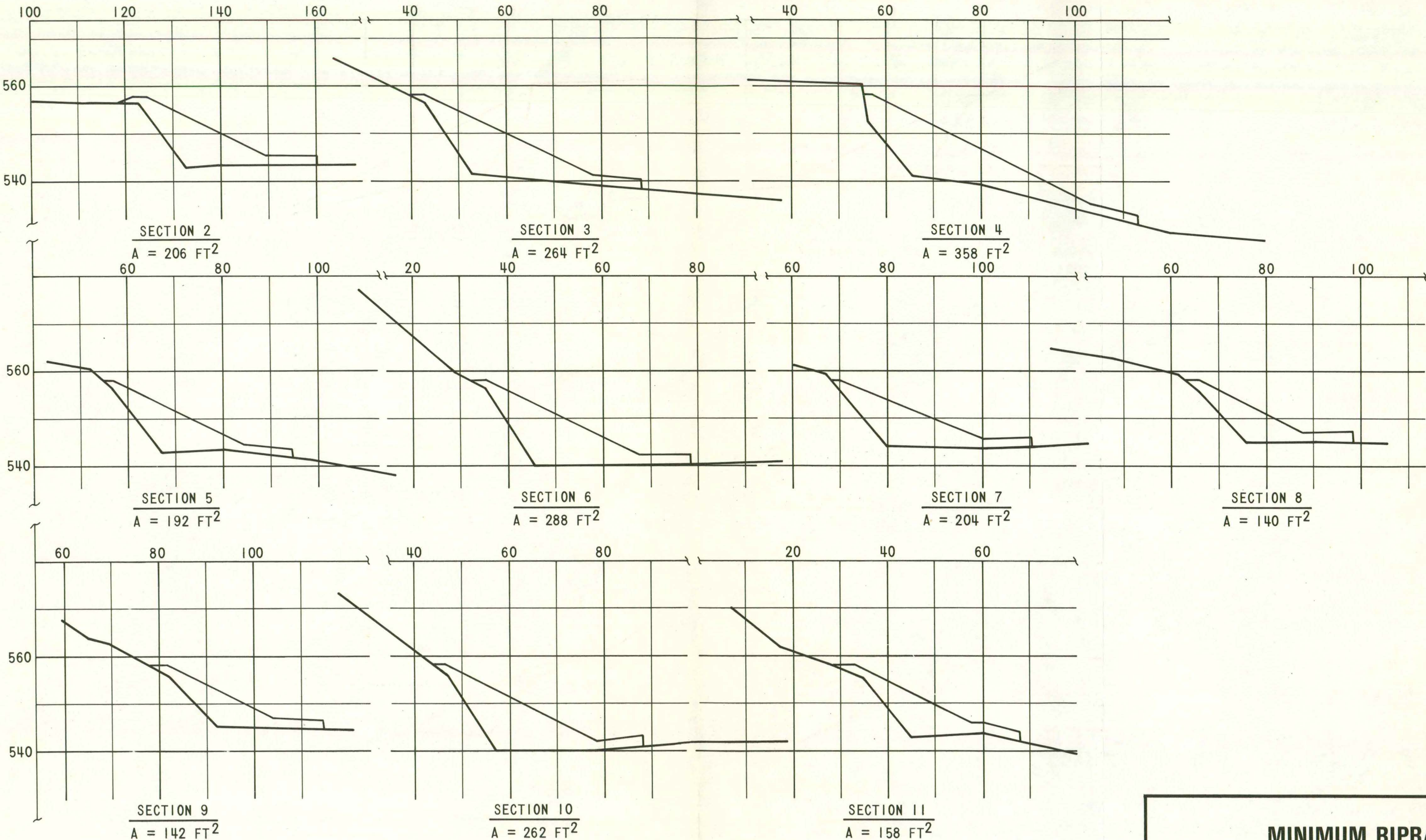
The recommended plan described below and its first alternative, both provide for protection of the touch clay zone by means of a riprap revetment. Their construction does not preclude additional provision of a sheet piling retaining wall in these few instances and provides for protection of the foundation of the sheet piling.

Our estimate of the cost of providing riverbank protection of the type shown in Figure 7 over 1 mile of river frontage through Wapello is $8,500,000. Because of high cost we cannot recommend this plan, but suggest its limited use for protection of isolated buildings not adequately protected by our recommended plan. A promising alternative to sheet piling of particular suitability where proximity of buildings prevents installation of "tie-backs" which we consider indispensible to the development of a successful sheet steel piling bulkhead, would be its replacement by a gabion retaining wall founded upon the tough clay. The exposed clay face would be protected with riprap. A 10-foot by-10 foot gabion section would suffice for a 1 on 2 sloping backfill. Particular designs would be developed for the protection of individual structures.

Minimum Riprap Revetment Plan

At the outset of this study we set the task of endeavoring to find the most economical solution, having reasonable hope of success. We considered that such a solution, if it could be found, would provide the best basis for elaboration designed to produce the most beneficial plan should such elaboration be found necessary or even desirable.

In our opinion the riprap revetment shown in typical sections in Figure 8 constitutes the closest approach to our least-cost-criterion. Briefly, it may be described as a riprap protection to the tough clay zone. A filter will be placed between riprap and and clay to prevent migration of fine materials through the revetment. Toe protection will be provided against anticipated erosion of the riverbed during floods and facing stone will be sized to achieve a stable side slope on the outside of a river bend with velocities as high as 10 feet per second.



MINIMUM RIPRAP REVETMENT PLAN

figure 8

The clay zone will thus be protected against erosion by heavily sediment laden waters and from weathering. Possible seepage pressures resulting from return flow from the lower sand will be offset by weight of the stone revetment. The presence of the filter will dissipate the negative pressure over a longer distance and prevent the loss of fine sand particles. It is recommended that continued observation of piezometric levels in this lower sand zone be made to provide more information on this important point.

The upper sand zone will receive no special attention under this plan. It is expected that in the first few years, isolated instances of slippage will occur in this zone where side slopes are presently steep and inadequately held with vegetation. Because the underlying clay will be stabilized, however, the steady progressive erosion of the sand zone will be stopped and stable side slopes will soon be achieved. It is not expected that any slope failures which may occur in the upper sand will materially damage the riprap revetment.

It will be in the interest of adjacent property owners to maintain vegetation upon the bank slope which constitutes their boundary. Where additional sheet piling is considered necessary to protect isolated structures, it is recommended that the cost of this protection be born by the property owner concerned.

The total estimated cost of minimum protection to 1 mile of river frontage under this minimum cost plan amounts to $1,500,000.

Recommended Protection Plan for Wapello

Threatened erosion whether resulting from increased wave attack consequent upon high levels in the Great Lakes or from river erosion has not generally been met by enthusiastic public action because of the relatively small number of people directly affected. Proposed remedial measures, usually involving large expenditures, are regarded as benefitting the relative few. Others become interested only after a passage of time when intervening property has been washed away and they realize that they are "next in line" for loss.

It is an unfortunate fact that in many cases the high cost of engineering works involved renders adequate erosion protection beyond the means of all but a few. Poorly contrived erosion protection measures meet with speedy failure with financial loss to those least able to support it. This frequently leads to despair and abandonment of the project and a passing-on of the problem to others.

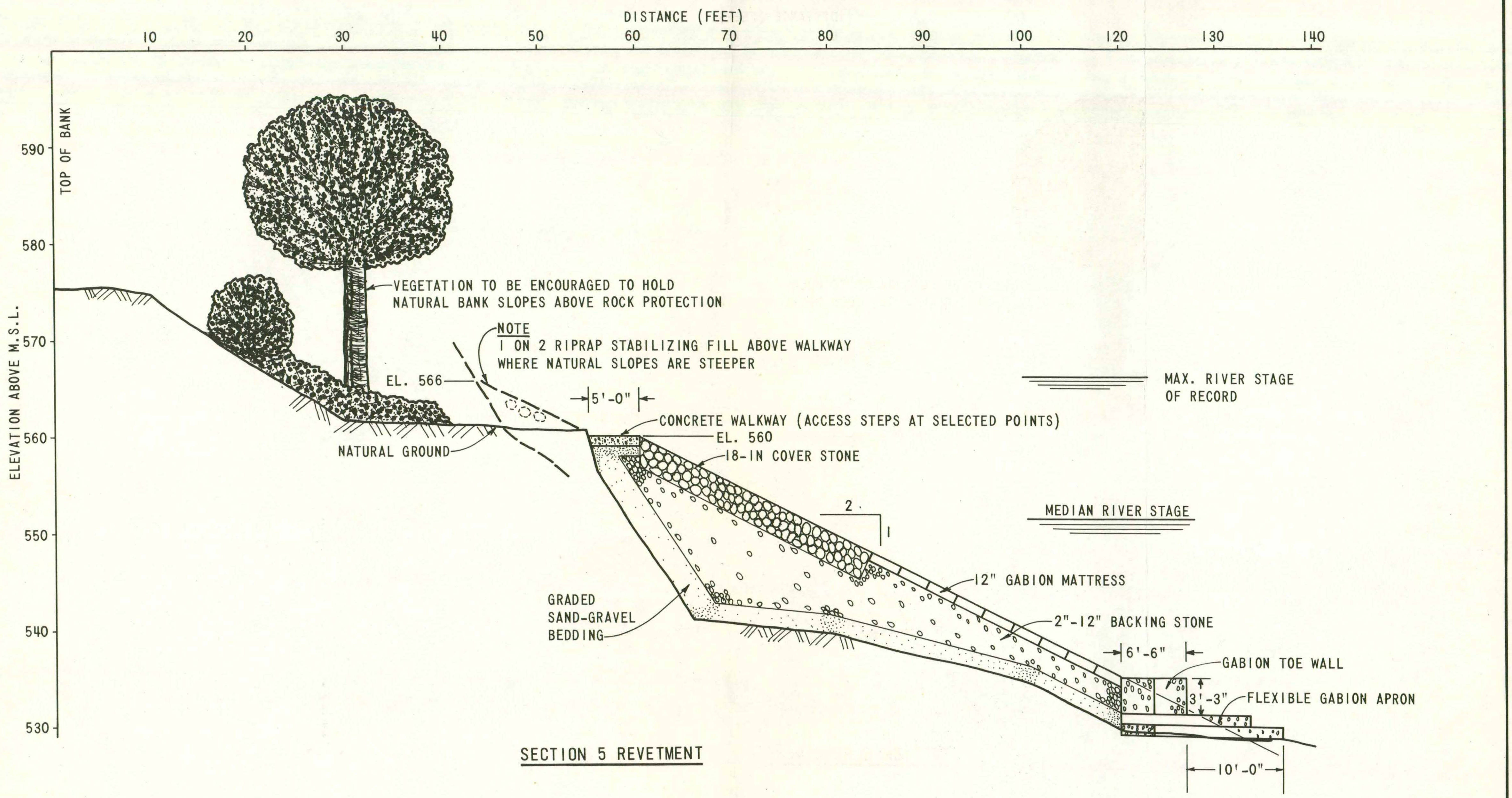
Because it may well be beyond the capability of those presently living along the threatened bank to "hold the line" and because erosion, though slow, is inevitable, threatening all in its path, there is wisdom in taking up action against it as a public enterprise. Public participation becomes far more palatable in those cases where an immediate benefit, inherent in the proposed remedial plan, can be plainly seen by all.

Such a benefit is realizable at Wapello and will result from a relatively minor extension of the "minimum cost" plan previously discussed. It is proposed that the riprap revetment be enlarged to support a 5 foot walkway at Elevation 560, running the entire length of the project. This walkway located about 20 feet below the top of the high bank and screened by a belt of protective vegetation will be made accessible to the general public by steps connecting to city streets.

The riverbank will then be available to the public for recreational use with negligible loss of privacy (or land) to the adjacent property owners.

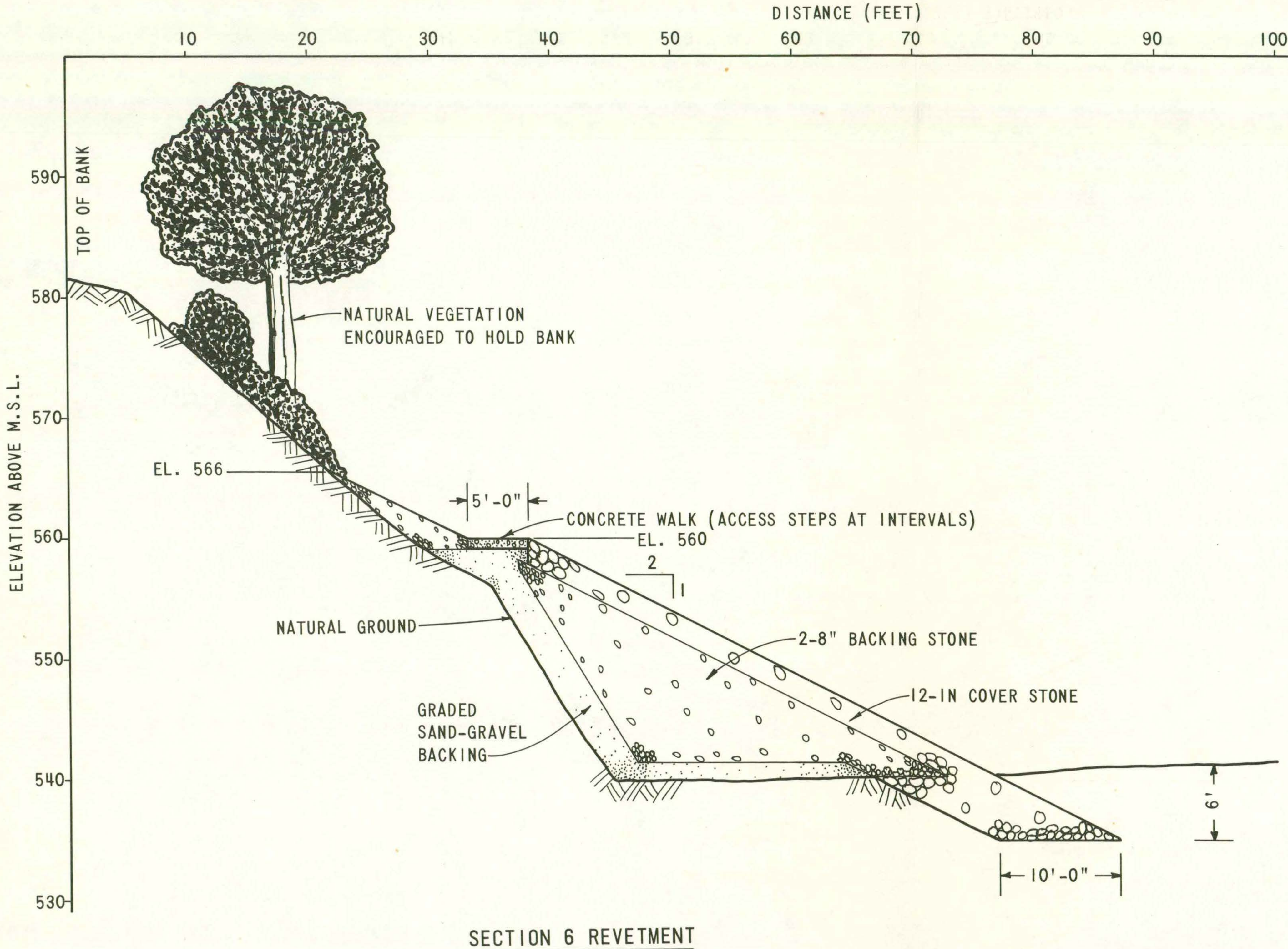
We believe that there would be little opposition to this plan by property owners who would gladly surrender any legal claims to ownership of the sloping bank where it is to be covered by protective works. The City Attorney has reported that the "high water mark" which constitutes the legal boundary is not, in his opinion, clearly established. In order to provide for maintenance of the revetment, we propose Elevation 566 as the high water mark in the protected area. Affected property owners should be required to relenquish any title they may have to property on the sloping bank below this elevation.

Figures 9 and 10 show typical cross sections of the river bank and protective works under this plan. Somewhat more conservative design is proposed upstream of the bridge where erosive attack by the river is more direct. Dimensions shown on Figures 9 and 10 should be interpreted



TYPICAL REVETMENT WALL UPSTREAM OF BRIDGE

figure 9



TYPICAL REVETMENT WALL DOWNSTREAM OF BRIDGE

figure 10

as indicative of the order of magnitude of sizes which should be more rigorously determined in final engineering design. They are shown here to illustrate the basis upon which the cost of this project has been estimated. The Corps of Engineers, Rock Island has suggested that the relative economics of providing a flexible precast concrete mat in lieu of the heavy riprap cover stone shown in Figures 9 and 10 be investigated in final design.

Provision will be included for maintaining a waterway to the existing boat launching ramp through the proposed revetment.

The estimated total cost of this recommended protective plan for Wapello is $1,946,100. A breakdown of costs for this plan is included in Appendix B to this report. It is recommended that the cost be born from public funds. An equitable distribution of costs between the Federal Government, State Government, and the City of Wapello should be negotiated. Riverbank property owners should donate any land required for the project and understand that they will remain responsible for maintenance of their exposed bank above Elevation 566.0.

PART IV

ENVIRONMENTAL ASPECTS

Flood Stage

The existing channel at Wapello is in an approximate state of equilibrium under existing discharges and sediment loads, and no material changes in these factors will result from construction of the recommended project. Encroachment into the river channel by the proposed revetment will in our opinion be rapidly followed by compensating erosion elsewhere in the cross section. Since the channel is reported to be aggrading, this erosion will most likely be of the sand deposits of the eastern bank.

Under the conservative assumption that no compensating erosion will occur, the reduced cross section following construction of the revetment at Wapello will result in a rise of about 0.4 feet above natural river stage between stages of 554 and 566 feet above mean sea level. Exact computation of this rise is difficult because channel bed form changes with stage and there are indications that plane-bed conditions hold at flood stage and that dunes and ripples will be present at lesser stages. In addition, riverbed erosion probably accompanies flooding.

In our opinion construction of the revetment at Wapello will result in considerably less than 0.4-foot rise in flood levels.

Sediment Load

The relatively small bank revetment proposed for Wapello is insignificant in comparison with the remainder of the river channel. Complete elimination of erosion of the west bank of Iowa River through Wapello will result in an annual reduction in total sediment load of approximately 6,300 tons. This amounts to less than one-tenth of 1 percent of the estimated total annual sediment load carried by the river.

The proposed revetment will consequently have no measurable effect upon downstream sediment load in the Iowa River but will vastly improve the appearance of the riverbank through Wapello as well as provide safety against erosion.

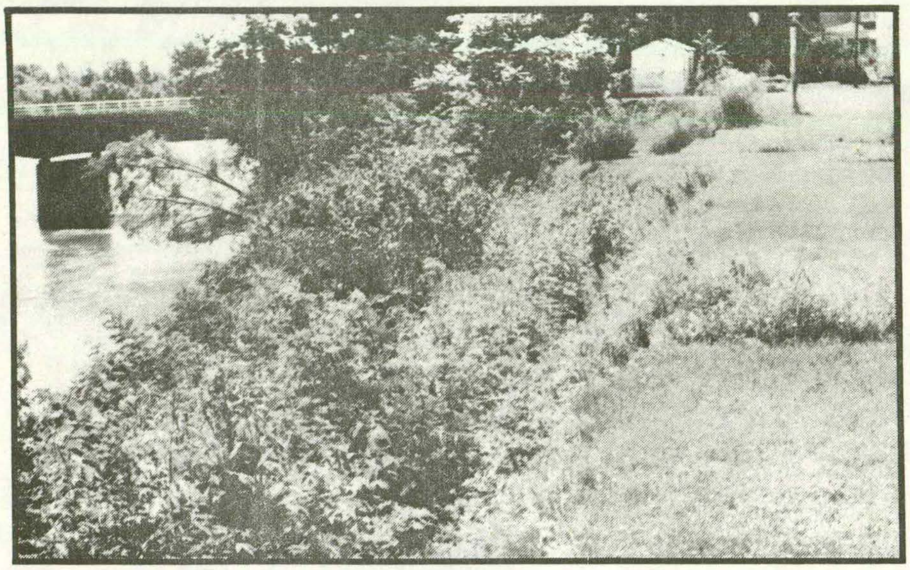
River Bank

The upper sand layer of the bank along the proposed revetment supports native river-bottom trees; box elder, silver maple, cottonwood, and sycamore. (Upland from the bank are scattered elms, black locust, ailanthus, and maples, associated with adjacent lawns.) Shrubs, weedy herbaceous plants, and grasses provide understory and ground cover. Riverbank sloughing has moved a number of cultivated shrubs and hedges from private lawns down onto the bank area. The relatively inaccessible slope and its vegetation provide habitat for year-round and seasonal songbirds, squirrels and other small mammals, and numberous lower animal forms.

Upper sand layer riverbank vegetation is flooded every three to four years and may be inundated from three days to three weeks. Bottomland tree species are tolerant of infrequent regular flooding, although seedlings may be damaged.

Movement of the sand layer has caused stands of vegetation to move downward as much as 20 feet. Relocated trees generally have remained upright and are vital to retarding further erosion. A number of large, well-established box elders are particularly noticeable and contribute stability. Soil movement has resulted in a few trees standing at nearly 45 degree angles.

Land adjacent to the riverbank in the project area is primarily private residential. Some semi-public buildings are located on the riverbank behind the business district. There is an established boat ramp at the east end of Vernon Street. Elsewhere the riverbank is relatively inaccessible for walking, fishing, and recreational use. A number of private access points (ladders and stairs) have been damaged or covered by bank movement. Scattered attempts to stabilize the bank with rubble, concrete blocks, and gravel have been partially successful but result in unsightly heaps that destroy vegetation and reduce wildlife use.



RIVER BANK VEGETATION, WAPELLO

Construction

Construction of the revetment wall will have minor temporary adverse environmental effects. It is anticipated that the revetment will be constructed during a low water stage. Access may be by existing city streets, or a special access along the bank of an old mill race may be possible. Construction easement for a materials stockpile is available at the upstream end of the project. Care should be taken to avoid disturbance to the site and surrounding vegetation. Clearing will be limited to those areas only where rock is to be deposited against the bank and access and stockpile areas.

We anticipate that much of the construction will be performed from barges and will proceed in a downstream direction. As the wall is extended, machinery and rock may be moved onto the wall for further extension.

Construction activities may temporarily and slightly increase local turbidity, noise, dust, and exhaust. A few trees near the underlying clay zone may be cleared prior to placement of revetment materials. Fish and wildlife habitat will be temporarily disturbed by noise, turbidity, and rock placement. Large tracts of undeveloped riverbottom are located on both banks upstream and downstream of the project area. The area that will be disturbed is small relative to the natural riverbank areas nearby. It is anticipated that construction activities will have only a slight temporary impact on a very localized area.

Project Effects

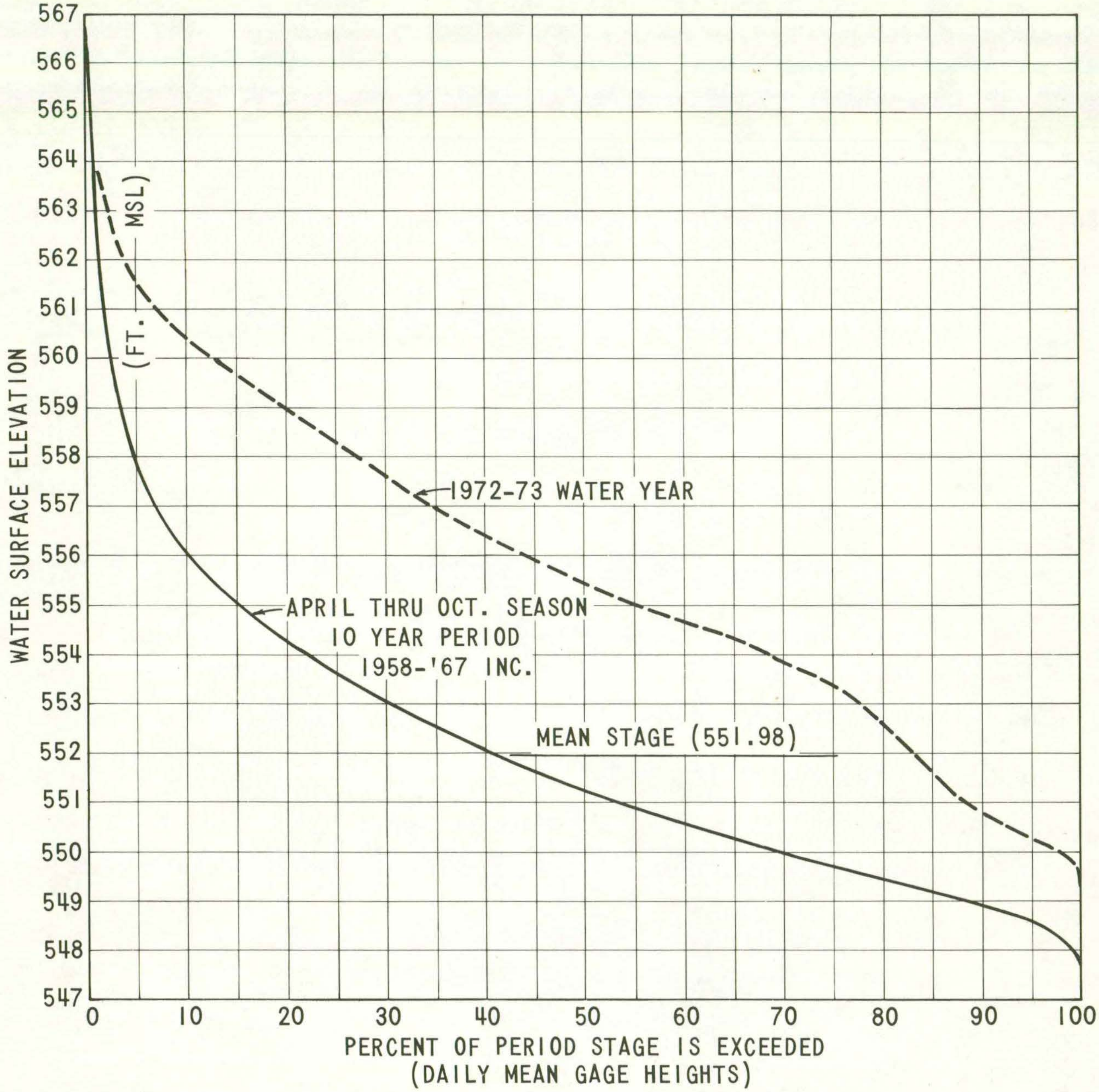
The revetment wall will be of long-lasting benefit to the community. Stabilization of the clay layer will allow the upper sand layer to attain a natural, stable slope. Threat to private property and the town will be removed. With the danger of persistent bank movement removed, the riverfront area can become an integrated attraction of the town. Natural flow of ground water to and from the river will continue unimpeded. No adverse effect upon Wapello's well water supply is expected. Lower bank stabilization will foster establishment of vegetation in the upper sand layer. Existing vegetation will continue to flourish while natural or planted trees and shrubs become established. Thus, even greater stability of the upper slopes against river scour and weathering will be achieved.

Addition of the revetment is not expected to adversely affect the small wildlife that use the riverbank. Change from the semi-natural existing condition to the wall, walkway, and well-vegetated bank will cause little disturbance. Improved vegetation may encourage use by songbirds, and squirrels and other small mammals.

The walkway, elevation 560, will be subject to infrequent flooding for short periods. Figure 11 indicates the percent of time that stages may be exceeded during the recreation season.

Development as a Public Asset

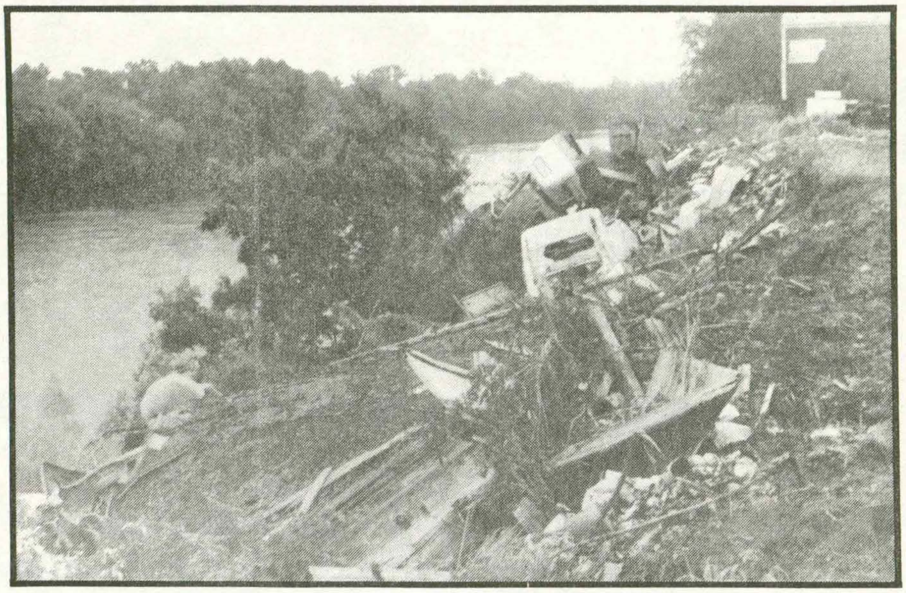
The revetment walk and walkway have excellent possibilities for community benefits through riverfront aesthetic development, moderate recreational use, and out-door education. The following actions are recommended to realize these possibilities and to relate the river resource to the community. It is suggested that civic groups be invited to assist private land owners in the following improvements as part of the forthcoming bicentennial celebrations. Youth groups could become community focus for improvement.



RIVER STAGE/DURATION CURVES

figure **11**

1. Remove unslightly rubble, dead vegetation, and trash previously dumped for bank stabilization. Exposed areas resulting from previous deposition of rubble on the upper slopes should immediately be seeded.



TRASH BANK PROTECTION, WAPELLO

2. Retain existing vegetation, particularly large firmly rooted trees. Provide additional plantings for ground cover, beauty, wildlife, shade, noise reduction (from recreational boats), and bank protection. Where necessary, the bank should be planted with native species tolerant of periodic flooding. Commercially available species include weeping willow, dogwoods, and silver maple. Suitable ground covers are birdsfoot trefoil, hall's honeysuckle, and crown vetch. The Soil Conservation Service and County Extension Offices in Wapello can provide information on vegetation and bank stabilization.

Private owners with land adjacent to the riverbank may consider planting arrangements to provide privacy and allow a view of the river. Appropriate plants include viburnums, cranberry, honeysuckle, coralberry, and native trees.

Following completion of the project the following developments are possible:

1. The access points and walkway may be related to Wapello parks and scenic features with informational and directional signs.
2. Encourage use of the walkway for fishing and leisure enjoyment.
3. Encourage use of the walkway by elementary, junior, and high school groups for study of town history, soils and erosion, engineering, effects of flooding, natural communities, aquatic life, etc. The walkway will provide excellent access to the bank and the river.

Moderate development of the riverfront area of the nature outlined above will vastly enhance the potential of the community's river location. The riverbank will be accessible to all with little threat to the privacy or security of adjacent property owners. Future development may attract visitors and indirect recreational benefits to the town.

PART V

CONCLUSIONS AND RECOMMENDATIONS

Summary

Observations carried out by the Corps of Engineers, Rock Island District, augmented by the detailed surveys and analyses made during the compilation of this report confirm that erosion of the western bank of the Iowa River at Wapello constitutes a hazard to the safety of an important area of the town. Erosion rates in this area are slow and average about 6 inches per year, but there is no natural phenomenon present that will prevent eventual recession of the bank upstream of the bridge amounting to several hundreds of feet.

Wapello is underlain by three layers of soils, an upper layer of about 23 feet of sand, an intermediate layer of about 17 feet of tough sandy silty clay followed by a medium sand. The bed of the river penetrates into the lower sand in only one of the cross sections surveyed in this study. Erosive action of river water is confined principally to the clay zone. Flood waters reach and attack the lower few feet of the upper sand zone. This material, normally of low resistance to erosion, in this instance is protected by heavy vegetation so that little, if any, erosion damage is reported during periods of high water.

Bank failure occurs in the form of localized slides of thin wedges of the upper sand zone which normally occur just after floods have receded. Our studies indicate that these occur when the underlying clay has been eroded by flow action and weathering to the extent that the sand overburden becomes unstable. Internal seeping groundwater pressures were not an important factor in the bank failures observed during our study but have not been discounted as being a possible contributory agent under extreme conditions.

Our observations show that erosion of the tough clay zone, although probably accelerated by the direct angle of attack resulting from the river meander to the north of the town, continues to be a factor downstream of the bridge where the channel is straight and where the direction of flow tends to be straightened by vane action of the bridge piers.

Proposals for erosion protection by channel straightening involve the additional necessity of erosion protection of the clay zone through the tower and are, therefore, not recommended due to high cost. Furthermore, modification of present channel alignment might introduce undesirable and unpredictable downstream effects due to interruption of the existing pattern of bar and bed deposits.

Provision of protection in the sand zone whether by steel sheet piling bulkhead or gabion retaining wall is not considered necessary for the full extent of town river frontage. Costs of such construction would be prohibitively high. Individual buildings, where in imminent danger of failure by bank erosion might be protected by such a wall provided the lower clay zone were also stabilized. We recommend that elsewhere, the riverbank above the high water mark be protected by individual property owners by encouraging and extending the existing vegetal cover and protection for individual buildings as may be required.

Two plans for controlling present erosion of the clay bank are presented, both of which involve riprap revetment extending along the mile long town river frontage. Of these, the first, described in this report as the Minimum Riprap Revetment Plan is aimed at achieving the required protection for minimum cost without regard to other factors involved. We estimate that such a plan would involve a total project cost of $1,500,000.

The recommended plan is almost identical to the above with the exception that public access be provided by means of a 5-foot walkway extending along the entire length of the revetment and connected at intervals to the top of the riverbank by means of steps. The walkway would be supported by the revetment and would be constructed at Elevation 560 about 21 feet below the elevation of the top of the bank. This walkway would be above water over 97 percent of the time during the recreational season. We recommend that high water mark be designated as being Elevation 566 along the riverbank at Wapello. This will enable protective works to be constructed and maintained to approximately the level of the highest flood of record. The estimated project cost of the recommended plan is $1,946,100.

The recommended protection plan will have no measurable effect upon the sediment load presently carried in the Iowa River past Wapello and will produce no predictable effect upon the river downstream.

Construction of the revetment will constitute a minor encroachment into the existing channel which could result in a rise of flood stage of about 0.4 feet if unaccompanied by consequent erosion. We believe that the channel through Wapello is approaching a state of equilibrium for present discharges and sediment loads. Construction of the revetment will initiate erosion offsetting the initial encroachment. Because there are indications that the riverbed is aggrading in this area, we believe that most of any erosion resulting from construction will be from existing sand bars on the opposite bank. When this erosion has taken place, the net effect of the construction on flooding will be very small.

Activities associated with construction of the project will have a transitory adverse effect upon river water turbidity and may temporarily disturb some of the small wildlife that use the riverbank. Completion of the project will result in an enhancement of the area by producing a slight reduction in sediment load and providing additional cover and food for wildlife.

Development of the recommended plan is predicted to provide, in addition to protection from property loss by erosion, a material benefit to the public in the form of aesthetic improvement and recreational development. The report outlines specific recommendations for improving the riverbank above the area directly protected by the proposed revetment. Suggestions are included for suitable development of the area as a public feature for recreation and education.

Because of benefits immediately available to the general public from the recommended plan, and realizing that far more than the line of property holders occupying the present riverbank are ultimately under threat of erosion loss, and because of the high cost of protection works required, we recommend that they be provided largely from public funds. Protection of privately-owned structures necessitating construction of a retaining wall founded upon the tough clay layer would be excluded from the project and would remain the responsibility of the individual.

Funding for this project is considered to be beyond the means of property owners immediately threatened with erosion. Costs should be born from public funds which, in our opinion, should be shared between the City of Wapello, the State of Iowa, and the Federal Government. The distribution of costs between these bodies will be determined after a study of availability of governmental support funds beyond the scope of this report.

Iowa Conservation Commission has expressed the opinion that all necessary land and easements should be obtained by the City of Wapello who should condemn any land not given or sold willingly for the project. A Citizens' Committee appointed for the purpose of expediting the project is currently negotiating these easements. Their initial report is that they believe that no costs will be involved.

Respectfully submitted,

STANLEY CONSULTANTS, INC.

By G. F. Tavene
G. F. Tavener

By S. Kinsman
Sharon Kinsman

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS

SS : Split-Spoon — 1 3/8" I.D., 2" O.D., except where noted
ST : Shelby Tube — 2" O.D., except where noted
PA : Power Auger Sample
DB : Diamond Bit — NX: BX: AX:
CB : Carboloy Bit — NX: BX: AX:
OS : Osterberg Sampler — 3" Shelby Tube
HS : Housel Sampler
WS : Wash Sample
FT : Fish Tail
RB : Rock Bit
WO : Wash Out

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon, except where noted.

WATER LEVEL MEASUREMENT SYMBOLS

WL : Water Level
WCI : Wet Cave In
DCI : Dry Cave In
WS : While Sampling
WD : While Drilling
BCR : Before Casing Removal
ACR : After Casing Removal
AB : After Boring

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils, the accurate determination of ground water elevations is not possible in even several days observation, and additional evidence on ground water elevations must be sought.

CLASSIFICATION

COHESIONLESS SOILS

"Trace"	:	1% to 10%
"Trace to some"	:	10% to 20%
"Some"	:	20% to 35%
"And"	:	35% to 50%
Loose	:	0 to 10 Blows
Medium Dense	:	11 to 29 Blows
Dense	:	30 to 59 Blows
Very Dense	:	≥ 60 Blows

(Blow counts: or equivalent)

COHESIVE SOILS

If clay content is sufficient so that clay dominates soil properties, then clay becomes the principle noun with the other major soil constituent as modifier; i.e., silty clay. Other minor soil constituents may be added according to classification breakdown for cohesionless soils; i.e., silty clay, trace to some sand, trace gravel.

Soft	:	0.00 – 0.59 tons/ft ^{2}
Stiff	:	0.60 – 0.99 tons/ft ^{2}
Tough	:	1.00 – 1.99 tons/ft ^{2}
Very tough	:	2.00 – 3.99 tons/ft ^{2}
Hard	:	≥ 4.00 tons/ft ^{2}

GENERAL NOTES

STS SOIL TESTING SERVICES of Iowa, Inc.
CEDAR RAPIDS · IOWA CITY · DAVENPORT · DES MOINES

LOG OF BORING NO. 1

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE: NEAR MECHANIC STREET, WAPELLO, IOWA	PROJECT NAME: WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
											Surface Elevation 583.2
1	SS	18	6	3		27.1					FILL - SILT - BRICKS - CINDERS Black
	WB								(3.5)	579.7	
2	SS	18	0	2					5		
	WB										FINE TO MEDIUM SAND, Brown, Loose to Medium Dense
3	SS	18	18	11		16.5		SP	10		
									(12.0)	571.2	
	WB										
4	SS	18	4	6		16.9		SP SW	15		
	WB										FINE TO COARSE SAND - TRACE GRAVEL, Brown, Loose to Medium Dense
5	SS	18	0	33					20		
									(22.0)	561.2	
	WB										
6	ST	24	22		5850	14.3	118	CL	25		SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Tough to Very Tough
	WB								30		
7	ST	24	12		*9000+	11.8	121	CL	(32.0)	551.2	

*Calibrated Penetrometer

Continued on Sheet #2

WATER LEVEL OBSERVATIONS		
W.L.		W.S. OR W.D.
W.L.	15' B.C.R.	A.C.R.
W.L.		

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids, Davenport, Iowa City, Des Moines

BORING STARTED	8/15/74		
BORING COMPLETED	8/15/74		
RIG	JOY	FOREMAN	RM
DRAWN	DAP	APPROVED	GRO
JOB #	64574	SHEET	1 of 2

LOG OF BORING NO. 1 (Continued)

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE NEAR MECHANIC STREET WAPELLO, IOWA	PROJECT NAME WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
										551.2	(32.0) Continued from Sheet #1
	WB								35		SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Very Tough
8	ST	24	18		4200	14.4	112	CL			
										544.7	(38.5)
	WB								40		SILTY CLAY - TRACE SAND, Gray, Very Tough
9	ST	24	15		*7000	17.9	112	CL			
	WB									538.7	(44.5)
10	SS	18	12	63		20.7		SP	45		FINE TO MEDIUM SAND - TRACE SILT, Gray, Very Dense
	WB								50		
11	SS	18	0	63						531.7	(51.5) Bottom of Boring
									55		Used 25' of NX Casing

*Calibrated Penetrometer

WATER LEVEL OBSERVATIONS				
W.L.		W.S. OR W.D.	BORING STARTED 8/15/74	
W.L.	15' B.C.R.	A.C.R.	BORING COMPLETED 8/15/74	
W.L.			RIG JOY	FOREMAN RM
			DRAWN DAP	APPROVED GRO
			JOB # 64574	SHEET 2 of 2

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids · Davenport · Iowa City · Des Moines

LOG OF BORING NO. 2

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE: NEAR JACKSON STREET, WAPELLO, IOWA	PROJECT NAME: WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Elevation	Depth	Description
									581.6	0	Surface Elevation 581.6
1	ST	18	9		*9000	12.6					FILL - SANDY CLAYEY SILT, Dark Brown
	WB										
									575.9	(5.7)	
2	SS	18	8	23		24.3					FINE TO MEDIUM SAND - TRACE SILT, Brown, Medium Dense to Dense
	WB										
3	3" ST	24	4			17.0		SP			
4	SS	18	6	36		13.7		SP			
	WB										Few Silt Seams
									567.1	(14.5)	
5	SS	18	12	24		7.7		SP SW			FINE TO COARSE SAND, Brown, Medium Dense to Very Dense
	WB										
6	SS	18	8	32/8"		18.5		SP SW			
	WB										
									558.1	(23.5)	
7	3" ST	24	20			15.5	112	CL			SANDY SILTY CLAY - TRACE GRAVEL (GLACIAL TILL), Gray, Very Tough
						21.7	101	CL			
8	ST	24	10		7270	10.4	120	CL			
	WB										
9	ST	24	18		7350	17.9	113	CL			
									549.6	(32.0)	

*Calibrated Penetrometer

Continued on Sheet #2

WATER LEVEL OBSERVATIONS			
W.L.		W.S. OR W.D.	
W.L.	23' B.C.R.	22' A.C.R.	
W.L.			

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids, Davenport, Iowa City, Des Moines

BORING STARTED 8/16/74	
BORING COMPLETED 8/16/74	
RIG JOY	FOREMAN RM
DRAWN DAP	APPROVED GRO
JOB # 64574	SHEET 1 of 2

LOG OF BORING NO. 2 (Continued)

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE NEAR JACKSON STREET, WAPELLO, IOWA	**PROJECT NAME** WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
									30		
										549.6	(32.0) Continued from Sheet #1
	WB										SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Very Tough
11	3" ST	24	20		*6200	15.9	109	CL	35		
					6280	16.1	114	CL			Fat Clay below 37.0'
12	ST	24	20		3380	33.2	98	CH		543.6	(38.0)
13	ST	24	18			15.6		SP			
						22.3		ML			
14	ST	24	16			18.1		SP	40		With Silt Seams above 41.0'
	WB										FINE SAND - TRACE SILT, Gray, Very Dense
15	SS	18	5	105		17.7		SP	45		
	WB										
									50		(51.5)
16	SS	18	7	111		15.0		SP		530.1	
											Bottom of Boring
									55		Used 25' of 4" Ø Casing

*Calibrated Penetrometer

WATER LEVEL OBSERVATIONS		
W.L.	W.S. OR W.D.	
W.L.	23' B.C.R.	22' A.C.R.
W.L.		

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids, Davenport, Iowa City, Des Moines

BORING STARTED 8/16/74	
BORING COMPLETED 8/16/74	
RIG JOY	FOREMAN RM
DRAWN DAP	APPROVED GRO
JOB # 64574	SHEET 2 of 2

LOG OF BORING NO. 3

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE NEAR SPRING STREET WAPELLO, IOWA	**PROJECT NAME** WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
											Surface Elevation 579.7
1	SS	18	6	6		22.0					SANDY SILT-TRACE CLAY, Dark Brown, Loose
	WB									577.7	(2.0)
2	SS	18	10	12		17.0		SM SP			
	WB								5		Silty above 5'
3	SS	18	10	12		18.3		SP			FINE TO MEDIUM SAND, Brown, Medium Dense
	WB										
4	SS	18	12	19		17.5		SP			
	WB								10		
5	SS	18	12	31		22.7		SP			
	WB										
6	SS	6	2	30		15.4		SW	15	564.7	(15.0)
	WB										FINE TO COARSE SAND, Brown, Dense
7	SS	6	5	50		13.1		SW	20		
	WB									557.4	(22.5)
									25		SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Very Tough to Hard
8	3" ST	24	10		*6500	13.5	118	CL			
9	ST	24	12		5390	13.2	121	CL			
	WB								30		
10	ST	24	13		8900	11.7	120	CL		547.7	(32.0)

*Calibrated Penetrometer

Continued on Sheet #2

WATER LEVEL OBSERVATIONS				SOIL TESTING SERVICES of IOWA, INC.	BORING STARTED 8/16/74	
W.L.		W.S. OR W.D.		Cedar Rapids, Davenport, Iowa City, Des Moines	BORING COMPLETED 8/16/74	
W.L.	14' B.C.R.	17' A.C.R.			RIG JOY	FOREMAN RM
W.L.					DRAWN DAP	APPROVED GRO
					JOB # 64574	SHEET 1 of 2

LOG OF BORING NO. 3 (Continued)

OWNER: CITY OF WAPELLO

ARCHITECT-ENGINEER: STANLEY CONSULTANTS, INC.

SITE: NEAR SPRING STREET, WAPELLO, IOWA

PROJECT NAME: WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
									30	547.7	(30.0) Continued from Sheet #1
	WB										SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Very Tough to Hard
11	ST	24	8		8450	14.9	117	CL	35		
	WB										
12	ST	24	22		9350	14.8	118	CL	40		
	WB									537.2	(42.5)
											FINE TO MEDIUM SAND, Gray, Dense to Very Dense
13	SS	18	10	52		19.5		SP	45		
	WB										
14	SS	18	0	74						530.2	(49.5)
									50		Bottom of Boring
											Used 24' of NX Casing

WATER LEVEL OBSERVATIONS				
W.L.			W.S. OR W.D.	
W.L.	14'	B.C.R.	17'	A.C.R.
W.L.				

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids · Davenport · Iowa City · Des Moines

BORING STARTED 8/16/74	
BORING COMPLETED 8/16/74	
RIG JOY	FOREMAN RM
DRAWN DAP	APPROVED GRO
JOB # 64574	SHEET 2 of 2

LOG OF BORING NO. 4

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE	**PROJECT NAME**
SOUTH OF PIKE STREET WAPELLO, IOWA	WEST RIVER BANK INVESTIGATION, IOWA RIVER

Surface Elevation 580.5

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
1	SS	18	4	5		11.6					FILL - SANDY SILT, Dark Brown
	WB									576.0	(4.5)
2	SS	18	3	5		28.2		SM	5		SILTY SAND, Dark Brown, Loose
	WB										
3	SS	18	12	11		14.3		SP SM	10	568.5	(12.0)
	WB										
4	SS	18	5	30		16.7		SP	15		FINE TO MEDIUM SAND, Brown, Medium Dense to Very Dense
	WB										
5	SS	5	5	54/5"		16.8		SP	20		
	WB									556.5	(24.0)
6	ST	24	12		5700	13.7	118	CL	25		SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Very Tough to Hard
	WB										
7	ST	12	8		*9000+	10.7	125	CL	30	549.5	(31.0)

*Calibrated Penetrometer

Continued on Sheet #2

WATER LEVEL OBSERVATIONS				
W.L.		W.S. OR W.D.		
W.L.	16'	B.C.R.	18'	A.C.R.
W.L.				

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids, Davenport, Iowa City, Des Moines

BORING STARTED 8/15/74	
BORING COMPLETED 8/15/74	
RIG JOY	FOREMAN RM
DRAWN DAP	APPROVED GRO
JOB # 64574	SHEET 1 of 2

LOG OF BORING NO. 4 (Continued)

OWNER	ARCHITECT-ENGINEER
CITY OF WAPELLO	STANLEY CONSULTANTS, INC.
SITE SOUTH OF PIKE STREET WAPELLO, IOWA	**PROJECT NAME** WEST RIVER BANK INVESTIGATION, IOWA RIVER

Sample No.	Type Sample	Sampling Distance	Recovery	Blows/ft.	Unconfined Compressive Strength-lbs./ft.^{2}	Water Content-%	Dry Density-lbs./ft.^{3}	Unified Class. Symbol	Depth	Elevation	Description
									30	549.5	(31.0) Continued from Sheet #1
	WB										SANDY SILTY CLAY - TRACE GRAVEL, (GLACIAL TILL), Gray, Very Tough
									35		
8	ST	24	12		*7500	14.6	115	CL			
	WB										
									40	539.5	(41.0)
9	ST	24	12		*6000	15.7	113	CL			SILTY CLAY - TRACE SAND, Gray, Very Tough
	WB										
									45	535.5	(45.0)
10	ST	18	8			16.5		SP			FINE SAND, Gray, Very Dense
	WB										
									50		
11	SS	18	0	70						529.0	(51.5)
											Bottom of Boring
									55		Used 25' of NX Casing

*Calibrated Penetrometer

WATER LEVEL OBSERVATIONS			
W.L.		W.S. OR W.D.	
W.L.	16' B.C.R.	18' A.C.R.	
W.L.			

SOIL TESTING SERVICES of IOWA, INC.
Cedar Rapids, Davenport, Iowa City, Des Moines

BORING STARTED	8/15/74		
BORING COMPLETED	8/15/74		
RIG	JOY	FOREMAN	RM
DRAWN	DAP	APPROVED	GRO
JOB #	64574	SHEET	2 of 2

SOIL TESTING SERVICES
OF IOWA, INC
CEDAR RAPIDS - IOWA CITY - DAVENPORT

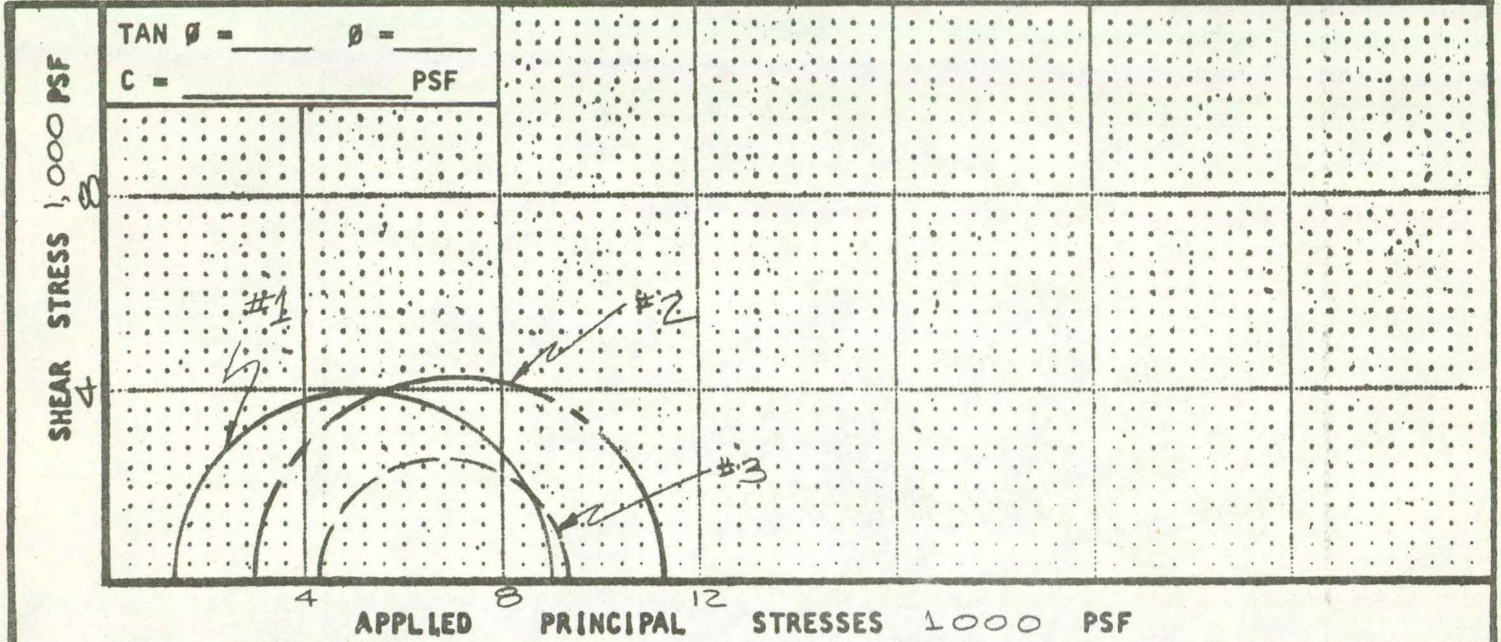
TRIAXIAL COMPRESSION TEST REPORT

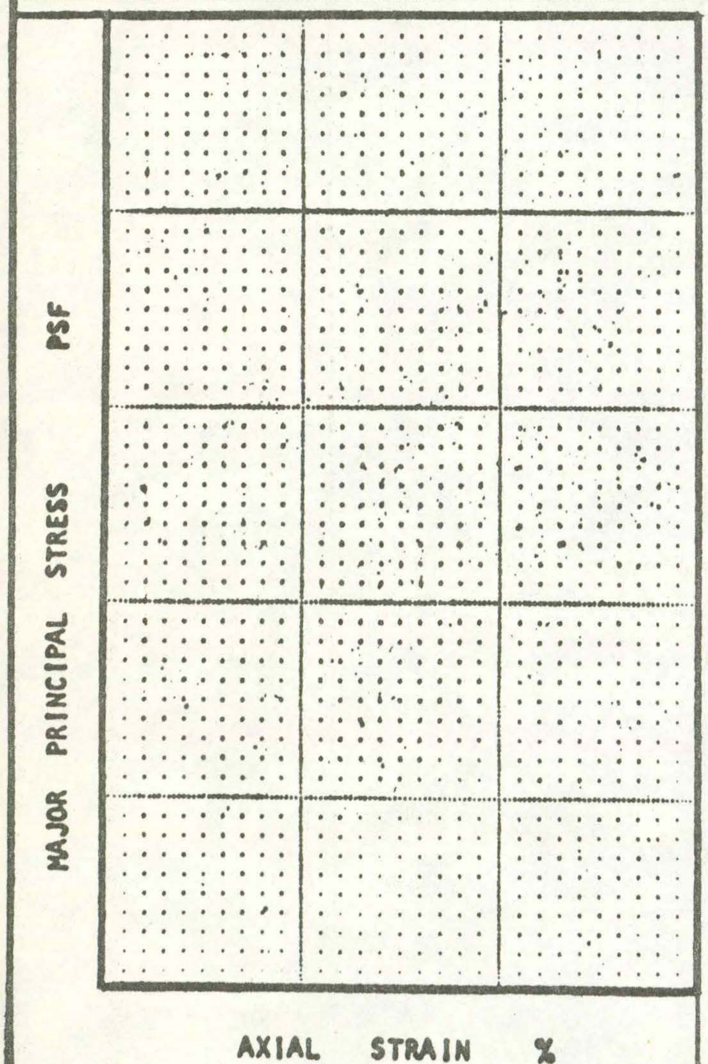
PROJECT NO. 64574   DATE 9-3-74

PROJECT NAME Iowa River Bank Stability Investigation

LOCATION B-3 B-2 (B-2)   DEPTH 34-36, 25-27 (25-27)

TAN Ø = ____ Ø = ____
C = ________ PSF





TEST DATA

		1	2	3	4
INITIAL	WATER CONTENT, ω_o %	16.1	13.5	24.1	
	DRY DENSITY, γ_d PCF	118.0	121.0	107.1	
	VOID RATIO, e_o				
	SATURATION, S_o %				
	SAMPLE DIAMETER				
	SAMPLE HEIGHT				
BEFORE TEST	W.C. AFTER SATURATION, ω_s %				
	SATURATION, S_c %				
	CONSOL. PRESSURE PSF				
	W.C. AFTER CONSOL. ω_c %				
	VOID RATIO, e				
AT FAILURE	PRINCIPAL STRESS DIFFERENCE, $\sigma_1 - \sigma_3$ PSF	7532	8310	5000	
	MAJOR PRINCIPAL STRESS, σ_1 PSF	8972	11,190	9320	
	MINOR PRINCIPAL STRESS, σ_3 PSF	1440	2880	4320	
	WATER CONTENT, ω_f %				
	VOID RATIO, e_f				
	STRAIN, ϵ_f %	9	18	16	

TYPE OF TEST Undrained Triaxial
TYPE OF SPECIMEN
SOIL DESCRIPTION Gray Sandy Silty Clay Trace Gravel (Glacial Till)
LL ____ PI ____
CLASSIF. CL   SPECIFIC GRAV. ____
REMARKS:

FO -21

APPENDIX B

WAPELLO RIVER BANK PROTECTION
PRELIMINARY PROJECT COST ESTIMATE
RECOMMENDED PLAN

Item	Description	Unit	Unit Cost	Quantity	Total Cost
1	Clear vegetation from protected sloping bank	L.S.	--	Job	$ 10,000
2	Dumped stone riprap	C.Y.	$ 26.00	$42,000	1,092,000
3	Filter bedding material	C.Y.	11.00	16,430	180,730
4	Gabions, filled and in place	C.Y.	13.00	8,250	107,250
5	Concrete walkway	C.Y.	80.00	490	39,200
6	Access steps	Each	1,000.00	6	6,000
7	Easements and right-of-way	L.S.	--	Job	10,000
8	Resurfacing of city street used for access	L.F.	10.00	2,640	26,400
					$1,471,580
	Design development estimate				220,720
	Total Estimated Contract Cost				$1,692,300
	Engineering and Project Administration				253,800
	TOTAL ESTIMATED PROJECT COST				$1,946,100