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Stream Bank Stability in Eastern Nebraska

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NATIONAL SEDIMENTATION LABORATORY OF THE
U.S. DEPARTMENT OF AGRICULTURE

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Water-Resources Investigations Report 03–4265

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Multiply	By	To obtain
centimeter (cm)	0.394	inch (in)
meter (m)	3.28	foot (ft)
kilometer (km)	0.622	mile (mi)
square meter (m^2)	10.8	square foot (ft^2)
square kilometer (km^2)	0.386	square mile (mi^2)
cubic meter (m^3)	35.3	cubic foot (ft^3)
centimeter per hour (cm/hr)	0.3937	inch per hour (in/hr)
meter per year (m/yr)	3.28	foot per year (ft/yr)
cubic meter per second (m^3/s)	35.3	cubic foot per second (ft^3/s)
gram (g)	0.03527	ounce avoirdupois (oz avdp)
kilopascal (kPa)	0.145	pound per square inch (lb/in^2)
kilonewton per meter (kN/m)	68.6	pound per foot
kilonewton per cubic meter (kN/m^3)	6.37	pound per cubic foot (lb/ft^3)

Elevation, as used in this report, refers to distance above the National Geodetic Vertical Datum of 1929 (NGVD 29).

Stream Bank Stability in Eastern Nebraska

By Philip J. Soenksen, Mary J. Turner, Benjamin J. Dietsch, *and* Andrew Simon

Abstract

Dredged and straightened channels in eastern Nebraska have experienced degradation leading to channel widening by bank failure. Degradation has progressed headward and affected the drainage systems upstream from the modified reaches. This report describes a study that was undertaken to analyze bank stability at selected sites in eastern Nebraska and develop a simplified method for estimating the stability of banks at future study sites. Bank cross sections along straight reaches of channel and geotechnical data were collected at approximately150 sites in 26 counties of eastern Nebraska. The sites were categorized into three groups based on mapped soil permeability. With increasing permeability of the soil groups, the median cohesion values decreased and the median friction angles increased. Three analytical methods were used to determine if banks were *stable* (should not fail even when saturated), *at risk* (should not fail unless saturated), or *unstable* (should have already failed). The Culmann and Agricultural Research Service methods were based on the Coulomb equation and planar failure; an indirect method was developed that was based on Bishop's simplified method of slices and rotational failure. The maximum angle from horizontal at which the bank would be stable for the given soil and bank height conditions also was computed with the indirect method. Because of few soil shear-strength data, all analyses were based on the assumption of homogeneous banks, which was later shown to be atypical, at least for some banks.

Using the Culmann method and assuming no soil tension cracks, 67 percent of all 908 bank sections were identified as *stable*, 32 percent were *at risk*, and 1 percent were *unstable*; when tension cracks were assumed, the results changed to 58 percent *stable*, 40 percent *at risk*, and 1 percent *unstable*. Using the Agricultural Research Service method, 67 percent of all bank sections were identified as *stable* and 33 percent were *at risk*. Using the indirect method, 62 percent of all bank sections were identified as *stable* and 31 percent were *at risk*; 3 percent were *unstable*, and 3 percent were outside of the range of the tables developed for the method. For each of the methods that were used, the largest percentage of *stable* banks and the smallest percentage of *at risk* banks was for the soil group with the lowest soil permeability and highest median cohesion values.

A comparison of the expected stable bank angles for saturated conditions and the surveyed bank angles indicated that many of the surveyed bank angles were considerably less than the maximum expected stable bank angles despite the banks being classified as *at risk* or *unstable*. For severely degraded channels along straight reaches this was not expected. It was expected that they would have angles close to the maximum stable angle as they should have been failing from an oversteepened condition. Several explanations are possible. The channel reaches of some study sites have not yet been affected to a significant degree by degradation; study sites were selected throughout individual basins and severe degradation has not yet extended to some sites along upper reaches; and some reaches have experienced

aggradation as degradation progresses upstream. Another possibility is that some bank sections have been affected by lateral migration processes, which typically result in shallow bank angles on the inside bend of the channel.

Another possibility is that the maximum expected stable bank angles are too steep. The stability methods used were well established and in essential agreement with each other, and there was no reason to question the geometry data. This left non-representative soil data as a probable reason for computed stable bank angles that, at least in some cases, are overly steep. Based on an examination of the cohesion data, to which the stable bank-angle calculations were most sensitive, both vertical and horizontal variability in soil properties appeared likely for many of the sites. Because a weak soil area or an interface of two differing soil areas in a bank can determine where the failure plane will be and what the factor of safety might be, it is not likely that the few soil tests done at each of the sites identified the critical soil parameters needed to accurately assess bank stability or to determine the expected stable bank angle for each bank section. At least for some bank sections, it appears that the summary results of bank stability for this study are overly optimistic. Although some individual bank sections may be accurately portrayed, it is not known which or how many bank sections are accurately classified without more extensive data to determine variability in soil shear strength.

If the variability of soil parameters, especially cohesion, can be determined for a site, and if the variability is small so that average or weakest values can be used to represent the banks, any of the methods demonstrated in this report can be used to make preliminary assessments of channel bank stability at future study sites. An electronic spreadsheet, developed for use with the indirect method, is included on a compact disk at the back of this report and can be used to make preliminary assessments of existing bank stability at study sites or to assess future bank stability under assumptions of degradation or aggradation by imposing projected changes on the existing bank geometry. The user needs cross-section data and estimates of the soil parameters—cohesion, friction angle, and ambient and saturated unit weight—to make the assessments. In addition, the spreadsheet can automatically compute the maximum uniform angle at which a bank section would be expected to be stable, for a given factor of safety, bank height, and soil parameters. For a bank with extensive variability in soil shear-strength, a method needs to be used that can account for multiple soil areas with differing parameters.

INTRODUCTION

Land-use changes in the loess area of the Midwestern United States (fig. 1) , resulted in stream channels becoming filled with sediment and debris by the early 1900s. This increased flooding of fertile bottomlands and affected the livelihoods of those trying to farm them. To alleviate frequent and prolonged flooding of these bottomlands, many stream channels, including thousands of kilometers in eastern Nebraska, were dredged and straightened to increase capacity and speed runoff (Speer and others, 1965). Although the original intent was realized, this engineering practice also reduced stream lengths, which increased channel gradients and stream power, and increased the ability of the flow to erode channel sediments. As a result, the modified channels of eastern Nebraska have experienced degradation, which heightened and steepened channel banks. Eventually, many banks reached a point where they became unstable and failed, thus widening the channel. This commonly occurs when banks become saturated during floods. As modified channels degraded, new oversteepened reaches formed at the upstream ends of the modified reaches and at the mouths of tributary channels along the modified reaches, thus initiating headward-progressing degradation and subsequent bank failures. Eventually, this process can affect an entire drainage system upstream from the original channel modification.

These channel responses have resulted in damage to highway structures, pipelines, and fiber-optic lines, and in the loss of land and the loss of access where structures were too expensive to justify repair or replacement (Simon and Rinaldi, 2000). Streambed degradation caused by straightening also is believed to have accelerated the drainage of saline wetlands along

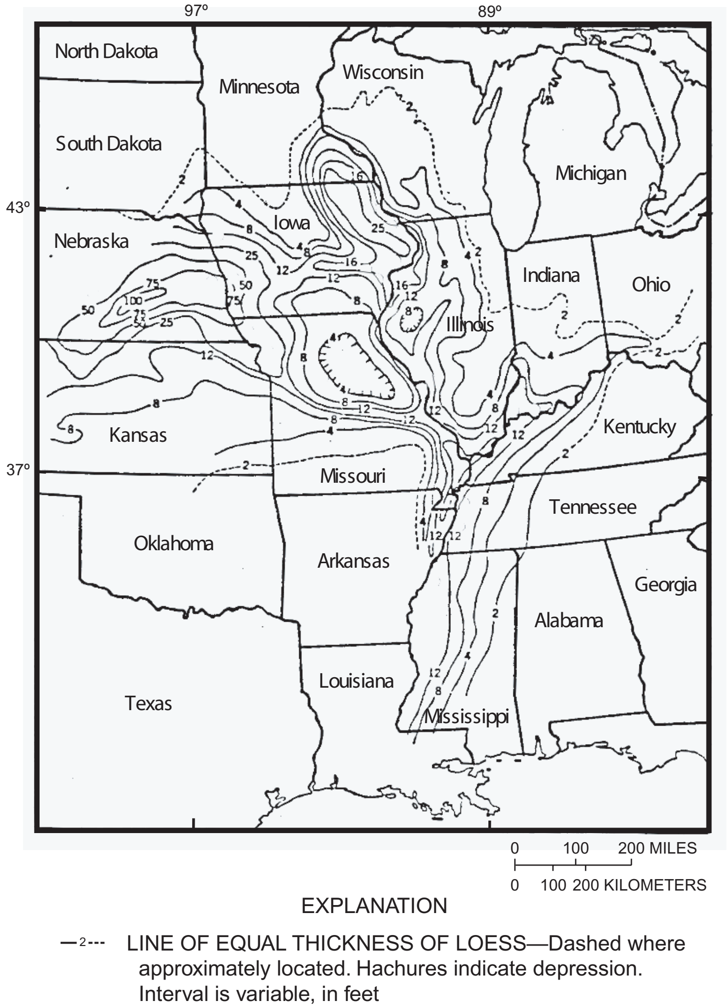


Figure 1. Location of loess area of the Midwestern United States and thickness of loess (modified from Luttenegger, 1987b).

Little Salt Creek (Farrar and Gersib, 1991) and Rock Creek (Natural Resources Conservation Service, 1996) in Nebraska. Degradation and channel widening in the loess area of the Midwestern United States has led to the collapse of bridges in West Tennessee (Robbins and Simon, 1983), southwest Mississippi (Wilson, 1979), Missouri (Emerson, 1971), and southeast Nebraska (Jerry Wallin, Nebraska Natural Resources Commission, oral commun., 1994). In western Tennessee, it was estimated that, on average, about 20 percent of the material eroded from stream channels was from the bed and 80 percent was from the banks (Simon, 1989a), which emphasizes the need to understand the bank-failure process. Large floods throughout the Midwestern United States in 1993 adversely affected many channels and caused the failure or closure of many bridges in Nebraska because of bed erosion and bank failure.

To address the need for information on bank stability, the U.S. Geological Survey (USGS), in cooperation with the Nebraska Department of Roads, Nebraska Natural Resources Commission (now part of the Nebraska Department of Natural Resources), Lower Platte South Natural Resources District, (NRD), Papio-Missouri River NRD, U.S. Army Corps of Engineers (USACE), and the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), National Sedimentation Laboratory (NSL), has completed a study to characterize and analyze the stability of stream channels in eastern Nebraska.

In addition to an analysis of stream bank stability, the study encompassed several other components. A database was created from the assessment of nearly 1,000 bridges for potential scour-critical conditions (U.S. Army Corps of Engineers, 1999). Aerial reconnaissance was used to estimate the stage of channel evolution, based on the work of Simon (1989b) for many channels in the study area (U.S. Army Corps of Engineers, 1998a). Trends in the water-surface elevation for a given discharge were examined at 145 stream-gaging stations in Nebraska (Chen and others, 1999). Channel evolution models were developed for two streams in the study area (North Branch West Papillion Creek and Little Salt Creek) to assess the effects of mitigation measures and urbanization (Langendoen and Simon, 2000). Streambed adjustment and channel widening in eastern Nebraska were documented by Rus and others (2003).

Purpose and Scope

The purpose of this report is to present the summary results for three methods of analyzing bank stability at approximately 150 sites in eastern Nebraska and to present a simplified method for estimating the stability of banks at future study sites. The report also includes average channel geometry data, and soil property data from field measurements and laboratory analysis, which were collected during 1995–99. Tables for this report are located in the Supplemental Data section at the back of this report.

Description of Study Area

The study area initially consisted of 23 counties in eastern Nebraska based on the interests of the cooperators. The area was later expanded to 26 counties (fig. 2)—adding Madison, Platte, and Saline—when sites considered beneficial to the study were selected in those counties. Eastern Nebraska is a glaciated region characterized by rolling hills, covered by easily erodible soil. Almost all of the study area lies within the Dissected Till Plains of the Central Lowland physiographic province (Fenneman, 1946); the western part of Butler County is in the High Plains of the Great Plains province. Loess deposits in eastern Nebraska are among the thickest in the Midwestern United States (fig. 1) and are primarily from the Gilman Canyon Formation, Loveland Formation, and Peoria Loess (Mandel and Bettis, 1995, 2000). Glacial till composed of poorly sorted materials lies beneath the loess mantle throughout much of the region and is exposed on lower slopes in some areas. Bedrock occurs in parts of the region, especially in southeastern Nebraska, but most streambeds lack bedrock control.

The dominant soil parent material is loess in most of the study area. In smaller areas, soils are primarily derived from loess and drift in the south and southwest, and from alluvium along some of the larger streams (fig. 3). Sites along smaller drainages in the uplands are likely to have loess-derived soils; sites along the larger drainages also could have soils derived from the underlying till or from alluvial deposits of silt, sand or gravel. Alluvial soil types vary in the region but generally consist of silt, silt loam, and silty-clay loam (Nebraska Soil and Water Conservation Commission, 1968; Soil Conservation Service, 1975). In the Elkhorn River Basin, western streambanks are sandy materials while streambanks in the eastern part of the basin are silty loess (Soil Conservation Service, 1971). The alluvial stratigraphy of the fine-grained deposits found in eastern Nebraska stream valleys are similar to those found in the De Forest Formation of western Iowa (Mandel and Bettis, 1995; 2000).

The study area (fig. 2) is included in parts of four major land-resource areas (MLRAs) (Soil Conservation Service, 1981). The Iowa and Missouri Loess Hills (MLRA 107) area has rolling-to-hilly topography that is highly dissected; the erosion hazard from runoff is severe on the uplands. The Loess Uplands and Till Plains (MLRA 102B) have well-defined drainages in the uplands while the till plains are level to gently rolling with less defined drainages. The Nebraska and Kansas Loess-Drift Hills (MLRA 106) have steep and strongly sloping areas generally consisting of glacial till, while the areas with flatter slopes consist of loess. The remaining part of the study area lies in the Central Loess Plains (MLRA 75). In the study area, these plains are gently rolling and mantled by loess, with the older Loveland loess exposed along the streams in some places.

All basins in the study area are part of the Missouri River Basin, and study sites were grouped according to smaller basins within it. Six stream basins were used for identification of most sites in the study area: Papillion Creek, Elkhorn River, Salt Creek, Little and Big Nemaha River, and Big Blue River Basins (fig. 2). The remaining sites were in smaller tributary basins of the Platte and Missouri Rivers and were grouped into the Missouri River tributary basins and the Platte River tributary basins.

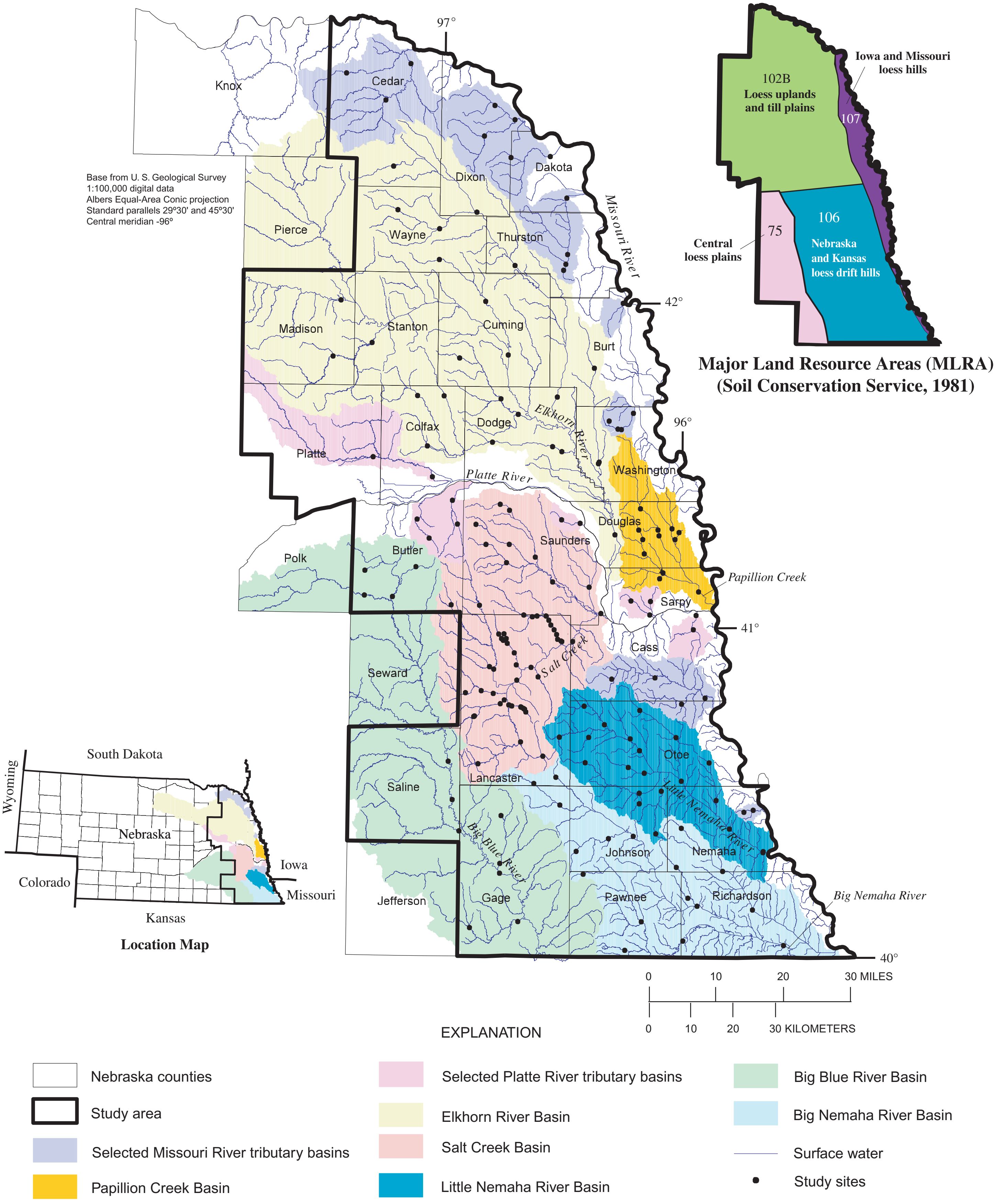
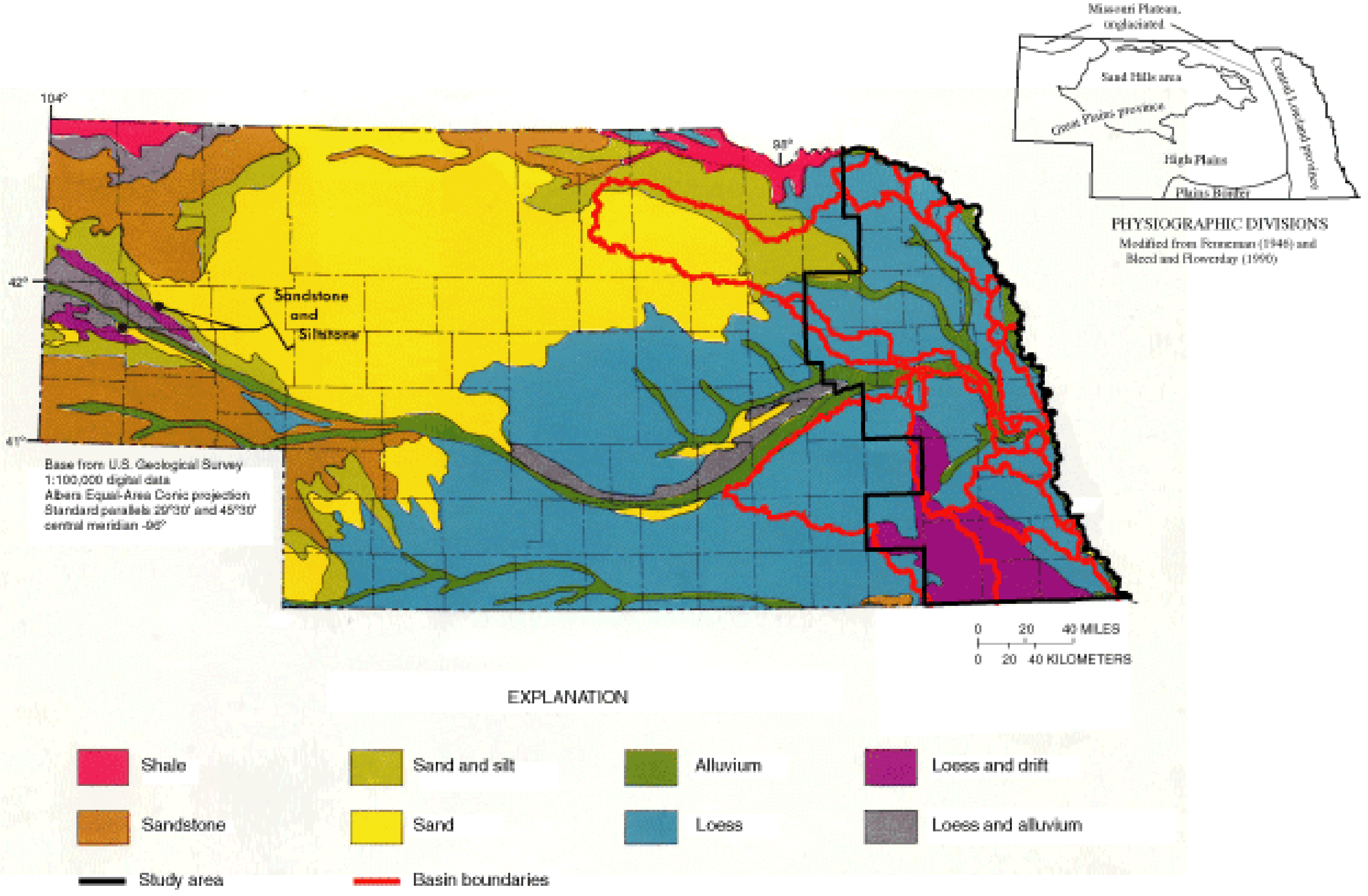


Figure 2. Location of study area showing river basins and sampling sites in Nebraska.



Base from U.S. Geological Survey
1:100,000 digital data
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30'
central meridian -96°

Modified from Fenneman (1946) and
Bleed and Flowerday (1990)

Figure 3. Generalized classification of soil parent materials showing study area and river basins, Nebraska (modified from Elder, 1969).

Acknowledgments

The findings presented in this report are the culmination of a cooperative effort among several agencies and individuals whose assistance was vital and greatly appreciated. The authors thank the landowners for permission to collect data on their property. The authors also would like to thank representatives from each of the cooperating agencies, specifically Don Jisa (Nebraska Department of Roads), Randy Behm (U.S. Army Corps of Engineers), Dan Schulz (Lower Platte South Natural Resources District), Marlin Petermann (Papio-Missouri River Natural Resources District), Andrea Curini (formerly of the National Sedimentation Laboratory), and Jerry Wallin (formerly of the Nebraska Natural Resources Commission) for their support and knowledge and for providing access to historical data. Thanks also go to colleagues and student interns in the USGS who provided assistance in collecting and analyzing data, and reviewing this report.

DATA COLLECTION AND DESCRIPTION

To analyze for bank stability, topographic and geotechnical data were collected along channel reaches at 145 sites in eastern Nebraska during 1995–99 (table 1). For this report, a reach was a section of stream channel as much as several hundred meters in length. Five sites—MRT 14, PC 6, ER 1, ER 2, and SC 20—did not have sufficient topographic data for use in bank stability analysis but were used in the streambed adjustment analysis presented by Rus and others (2003). Topographic surveys were made to obtain stream channel cross sections, field tests in boreholes were made to obtain shear strength parameters of the channel bank material, and samples of the channel banks were collected for laboratory analysis to obtain other engineering properties. Sites were selected based on the need to analyze for streambed adjustment and channel widening, as reported by Rus and others (2003), as well as to analyze for channel bank stability. Sites were distributed among the major drainage basins of the study area and were individually selected based on the availability of historic streambed-elevation data. All of the sites were located at bridges or culverts because the majority of historical data were associated with them. These structures were good landmarks for isolating streambed data from several sources into one location and for establishing reference points for future comparisons and surveys.

Topographic Data

A topographic survey of at least one stream-channel reach at each site was made to obtain multiple channel cross sections for bank-stability analyses.

Surveying

Channel-reach surveys were performed using a Sokkia Set II B electronic total station. A local coordinate system of northing, easting, and elevation was referenced to horizontal and vertical control points established at each site; this allowed each site to be surveyed later on the same coordinate system. The surveying instrument was approximately referenced to north by means of a magnetic compass with adjustments for declination as determined from USGS 1:100,000-scale topographic maps. After the topographic survey was made, the control points were surveyed again to confirm that the instrument was still measuring within 1 centimeter (0.03 feet) of the known coordinates. All survey points were corrected for the effects of temperature and atmospheric pressure, and for curvature and refraction.

The initial channel-reach surveys generally consisted of a combination of channel cross sections and selected ground and channel-bed shots not on the cross sections to define the top of the channel bank, and the *thalweg*, which is the deepest point in the channel. The reaches surveyed were typically three to four channel widths long; and all surveys included a cross section at either the upstream or downstream edge of the bridge or culvert structure for use in the streambed-adjustment analysis. Most surveys were made on one side of the structure with about four cross sections; some surveys were made both upstream and downstream from the structure with as many as 20 cross sections. Because of time constraints or dense foliage, some later surveys consisted only of channel cross sections. This report focused on channel widening caused by streambed adjustment rather than by lateral channel migration; therefore, straight reaches were preferred for surveying. However, in some cases, no straight reaches were present.

Average Channel Site Geometry

Bank heights, bank angles for left and right banks, and channel width at the top and toe of the banks were determined from the cross-section data. Bank heights in this report are defined as the vertical distance from the toe of the bank to the top edge of the same bank. Bank angles, referenced to horizontal, were characterized from the top of the bank to the toe of the bank in four ways—unweighted, and weighted vertically, horizontally, and linearly. Unweighted bank angles were computed as the angle from the point at the top of bank directly to the toe of the bank regardless of the points between. For weighted angles, the angles between each set of adjacent surveyed points along the bank section were multiplied by the vertical, horizontal, or linear distance between the points. The sums of the resulting values were divided by the total vertical, horizontal, or linear distance from the top to the toe of the bank to find the corresponding weighted angles. The different weighted angle calculations were done to provide several measures of individual bank-section angles for use in the development of a simplified method of bank analysis that could be used at future sites of interest. Channel widths were computed as the distances between the left and right top-of-bank and toe-of-bank points for each cross section. For summary purposes, the average (mean) values for each of the above measures of bank height, bank angle, and channel width were computed (table 2). Geometry data from both the site averages and the individual bank sections were used in later analyses. Because bank stability related to degradation and not to meandering or lateral migration was analyzed, cross sections on channel bends were not used.

Geotechnical Data

Geotechnical properties of the channel banks and streambeds were determined for 147 of the study sites by in-place soil testing and laboratory analyses of soil samples. Only geotechnical data for the channel banks were used for the analyses documented in this report.

Soil Testing and Sampling

Information about the shear-strength properties of the soil is essential for the analysis of channel-bank stability. Using an Iowa Borehole Direct-Shear Device (Spangler and Handy, 1973, p. 470–472) and the multistage method (Lutenegger and Hallberg, 1981; Lutenegger, 1987a), one or more Borehole Shear Tests (BSTs) were done in the channel banks at 147 study sites. The BST instrument does direct-shear tests on the walls of a borehole to determine values of total shear strength for corresponding values of applied normal stress. From a plot and regression of the data points, cohesion and friction angle, the individual components of total shear strength, were computed.

Boreholes of 7.6 centimeter (3-inch) nominal diameter were prepared manually for testing and sampling at most sites using a bucket auger and a reamer. Using a core sampler with a slide-hammer attachment, soil samples to be analyzed for soil unit-weight, moisture content, and degree of saturation were obtained from the bottom of each borehole at 147 sites; sample volumes were 93.4 cubic centimeters (cm^3). The samples were placed in metal containers and sealed with tape to preserve the ambient moisture representing existing conditions. At 91 sites, samples to be analyzed for particle size were obtained from the augered material taken at the depth of the BST; at 28 of those sites, a part of those samples also were analyzed to determine plasticity index. Logs of the bank material were made based on inspection of the soil as it was removed from the borehole and by examining nearby exposed bank faces; these were used in later evaluations of the BSTs.

For sites with the highest banks, a small trailer-mounted auger-drill rig was used to drill boreholes to depths not practical for hand augering. After the desired depth was nearly reached by drilling, a Shelby tube was pushed down about 15 to 30 centimeters (6 to 12 inches) into the bottom of the borehole to prepare it for the BST and to obtain material from which the soil samples were collected. BSTs and soil samples to a depth of 7.4 meters were obtained this way.

BSTs were done near the bottom of the boreholes. Using gas pressure, an outward (normal) force was applied to two conventional-style, 32 square centimeter (5 square inch), serrated shear plates suspended on opposite sides of the borehole. Time was allowed for the soil to consolidate (typically 15 to 30 minutes) and for pore water to dissipate out of the zone in proximity to the plates where shearing of the soil would occur. Then the plates were pulled axially along the borehole with increasing force until the soil next to the plates was sheared; the measured shear stress at failure (maximum applied axial force) and the applied normal stress were recorded. This represented a single stage of the BST, which usually was repeated six to eight times in the same location with incrementally larger normal stresses and with fairly uniform consolidation times (typically 7 to 8 minutes) between stages. With each stage of the test, the shear zone should occur The data were plotted after corrections were made to compensate for any non-zeroing of the stress-gage dials. BSTs that appeared questionable usually were repeated after the shear head was rotated 90 degrees (°) or was moved vertically to test fresh material. Preliminary results from the BSTs were computed in the field; final results were computed in the office after the analytical results from the soil samples were received.

Laboratory Soil Analyses

Samples to be analyzed for soil unit weight, soil moisture, degree of saturation, and particle size were delivered to the Soil and Plant Analytical Laboratory at the University of Nebraska–Lincoln. The soil unit-weight samples were weighed in the container, dried, and reweighed in the container; the containers then were cleaned and weighed. All measurements were in grams (g) as mass. The mass quantities of the ambient and dry soil sample and of the sample water were derived from the measurements.

The ambient soil unit weight (table 3) represents the soil condition at the time of sampling; values for the samples were computed using equations from Coduto (1999, p. 100):

$$\rho_{amb} = \frac{M_{amb}}{V} \tag{1}$$

where ρ_{amb} is the density of the ambient soil, in grams (mass) per cubic centimeter,

M_{amb} is the mass of the ambient soil, in grams, and

V is the total volume of the soil, in cubic centimeters;

$$\gamma_{amb} = \rho_{amb} g \tag{2}$$

where γ_{amb} is the unit weight of the ambient soil, in kilonewtons per cubic meter, and

g is the acceleration due to gravity, 9.81 meters per second squared.

The saturated soil unit weight (table 3) represents the soil condition when all the voids in the soil become filled with water; values for the samples were computed using an equation modified from Lambe (1951, p. 12; used density in place of unit weight of water and mass in place of weight of dry sample), and an equation from Dunn and others (1980, p.17):

$$e = \frac{G_s \rho_w V}{M_s} - 1 \tag{3}$$

where e is the void ratio or relative volumes of voids (air and water) and solids of the soil, dimensionless,

G_s is the specific gravity of the soil solids, assumed to be 2.70 based on the range for moist soils (Coduto, 1999, p. 101) and the value for Iowa loess soil (Spangler and Handy, 1973, p. 166), dimensionless,

ρ_w is the density of water, 1.00 grams per cubic centimeter, and

M_s is the mass of the soil solids, in grams;

$$\gamma_{sat} = \frac{(G_s + e)}{1 + e}\gamma_w \tag{4}$$

where γ_{sat} is the unit weight of the soil when saturated with water, in kilonewtons per cubic meter, and

γ_w is the unit weight of water, 9.81 kilonewtons per cubic meter.

The moisture content (table 3) of the soil samples was computed using an equation from Coduto (1999, p. 97):

$$w = \frac{M_w}{M_s} \times 100 \tag{5}$$

where w is the moisture content of the ambient soil, in percent, and

M_w is the mass of the soil water, in grams.

The degree of saturation (table 3) of the soil samples was computed using an equation modified from Coduto (1999, p. 106):

$$S_D = \frac{wG_s}{e} \qquad (6)$$

where S_D is the degree of saturation of the ambient soil, in percent.

Particle-size distribution, as percentages of gravel, sand, silt and clay, was determined by a 4-point hydrometer test. If the sample contained sufficient coarse material, a sieve analysis also was done. The laboratory made a determination of soil textural classification based on the USDA system (Schoeneberger and others, 1998) with National Soil Information System (NASIS) codes (table 3).

Samples to be analyzed for Atterburg limits (liquid limit, plastic limit, and plasticity index) were delivered to the National Soil Survey Laboratory of the Natural Resources and Conservation Service (NRCS) in Lincoln. Sample volumes of 500 grams or more were sieved, and the liquid limit was established by determining the moisture content in which the sample was able to close a groove under standard shaking (Lambe, 1951). The plastic limit was found by determining the moisture content in which a thread of the sample (of standard size) began to crumble when rolled (Lambe, 1951). The plasticity index then was computed as the liquid limit minus the plastic limit. Values for 28 sites were determined (table 3).

Evaluation of Borehole Shear Tests

Pore-water pressure (u) can affect the total shear strength measured by the BST (Spangler and Handy, 1973; Lutenegger and Hallberg, 1981). In such cases, the computed values of cohesion and friction angle are referred to as apparent values. The effective values of cohesion (c') and friction angle (ϕ') are those attributed only to the soil structure and are the values needed for channel-bank stability analysis. If pore water dissipates out of the shearing zone during the consolidation time between individual stage tests, the BST should not be affected by the effects of positive pore-water pressure. This should be especially true for sands and dry cohesive soils (Lutenegger and Hallberg,1981). If that is the case, the BST is a drained test, and the apparent shear stress measured is equal to the effective strength of the soil. The friction angle of the soil is lowered based on the degree of saturation of the soil and goes to zero when completely saturated (Lutton, 1974). If the excess pore water cannot be drained quickly enough, as can happen with saturated or high-plasticity clays, pore pressure is positive, and the BST is an undrained test with apparent strength parameters (Lutenegger and Hallberg, 1981). Generally, the greater the degree of saturation or the more clay in the soil, the greater the consolidation time needs to be to dissipate the excess pore water. Alternatively, some soil, such as silt and clay, can develop a high apparent cohesion from negative pore-water pressure through the process of drying (Spangler and Handy, 1973, p. 441; Simon and others, 1999a).

Preliminary manual calculations of cohesion (y-intercept) and friction angle (slope) were made at the site by a least-squares regression on the range of data that appeared to define a relation known as the Mohr-Coulomb failure envelope for the soil (Lutenegger and Hallberg, 1981). The BSTs later were recalculated after a calibration adjustment for the instrument was incorporated and other independent results were examined to infer possible effects of positive or negative pore-water pressures. These other results included moisture content, degree of saturation, and particle size of the soil; borehole logs; BST consolidation times; sorption curves of soils, and other BSTs. Sorption curves—negative pore-water pressure or capillary potential as related to moisture content or degree of saturation—for different textural classes of soils (Spangler and Handy, 1973, p. 222-231) were used as a guide to estimate possible effects of negative pore water pressure on BSTs.

According to Lutenegger and Hallberg (1981), interpretation of BSTs to determine effective strength parameters “should be based on judgement of the drainage characteristics of the soil and test conditions.” For this report points for regression were selected, or BST results were not used, based on guidelines given by Lutenegger (1987a) and Lutenegger and Hallberg (1981). Low initial points sometimes were eliminated because of apparent inadequate seating of the shear plates (figs. 4C and 4D)—caused by inadequate normal stress for the given soil condition. The local slope of such points commonly will project to a negative cohesion, which is a physical impossibility. Although Lutenegger (1987a) suggests not using the first point routinely, many were found to fit a regression line consistent with other points. Data points at high values of normal stress sometimes were eliminated because of the apparent effects of positive pore-water pressures or because the expansion limits of the BST device appeared to have been reached (figs. 4B and 4D). These situations were identified by a flattening of the slope or a negative slope at the upper end of the data.

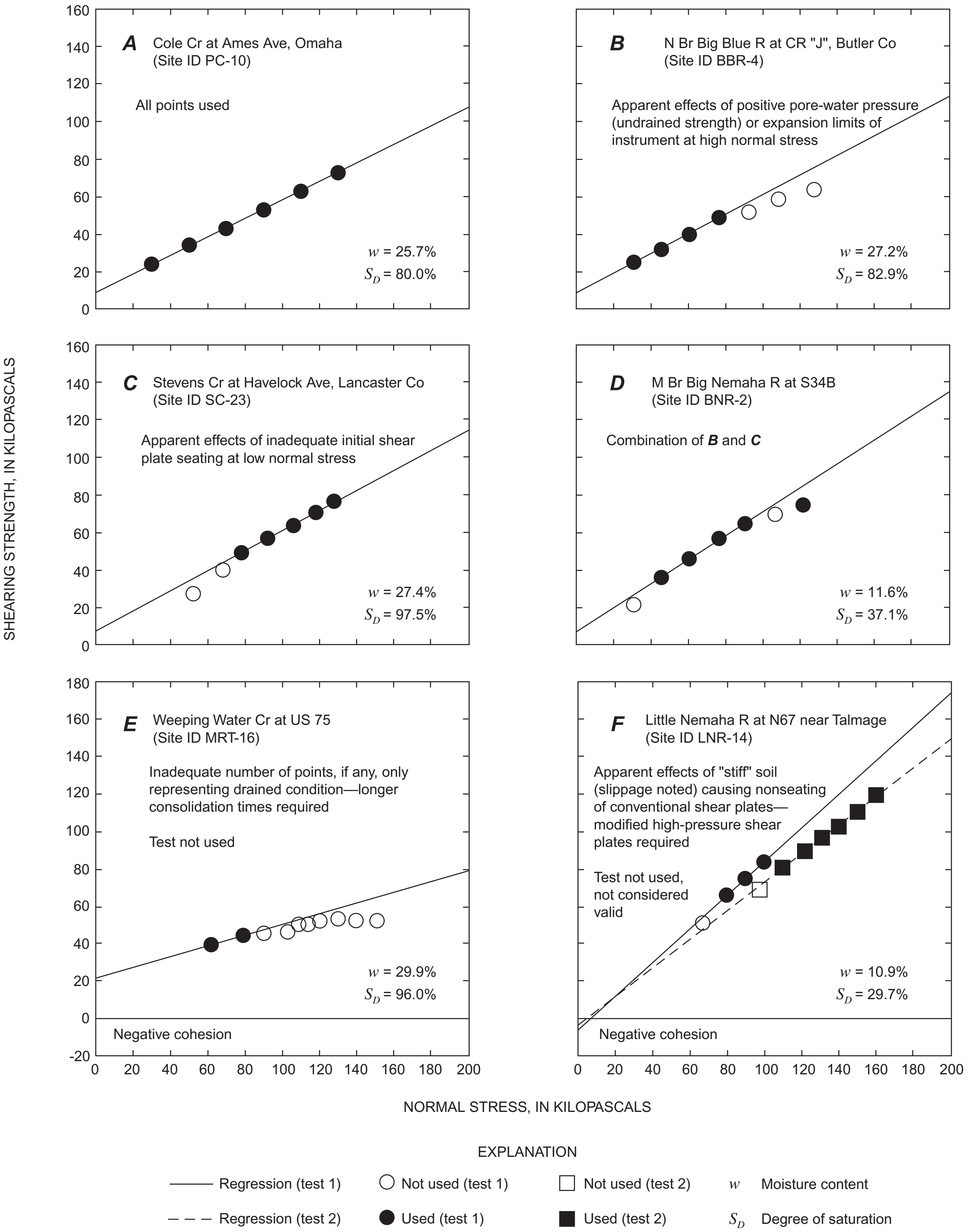


Figure 4. Examples of borehole shear test data and interpretations, and values of moisture content and degree of saturation at time of tests.

For some tests, positive pore-water pressure or inadequate seating of the plates appeared to affect most or all of the data points (figs. 4E and 4F) to such an extent that the test results were not used in the bank-stability analysis. Based on sorption curves, results of a few BSTs with apparently high cohesions and low values of moisture content or degree of saturation also were considered questionable. The sorption curves showed that for the loess and clay loam soil the capillary potential increased rapidly with decreasing values of moisture content below about 25 percent of dry weight (or degree of saturation below about 55 percent for clay loam soil).

A summary of the BST status, except for those not considered valid (such as fig. 4-F), are listed in table 3. Results considered questionable (such as fig. 4-E) are listed, but are noted as not being used for further analysis. Cumulative frequency diagrams of the BST results considered useable for bank-stability analysis show that most of the sites had cohesions between 6 and 18 kPa (kilopascals) and friction angles between 24 and 37° (fig. 5). For comparison, average (mean) values for loess in western Iowa (Lohnes and Handy, 1968) and western Tennessee (Simon and Hupp, 1992), and a range of values for Kansas and Nebraska loess, cited from other sources by Lohnes and Handy (1968), indicated cohesions and friction angles generally in the same range as that found in this report, with the exception of cohesions ranging from 34.5 to 69.0 kPa cited by Lohnes and Handy (1968) (see fig. 5). The data from western Iowa and western Tennessee are from BSTs and were considered to represent drained conditions.

Shear-strength data from BSTs also were collected from alluvial channel banks for three bridge site studies in Mississippi (Turnipseed and Wilson, 1992; Turnipseed and Baldwin, 1992; and Wilson and Turnipseed, 1993). Excluding sand material, of which little was encountered in eastern Nebraska, average cohesion from the Mississippi studies was 13.8 kPa with a range of 9.2 to 17.7 kPa. Average friction angle was 27° with a range of 16 to 35°. The authors of the Mississippi reports noted that "Shear-strength data obtained using the BST have compared reasonably well with the results of triaxial shear-strength tests …"; this assertion was based on work by Thorne and others (1981) and on tests made by the Mississippi Department of Transportation. Regarding the BST results for western Iowa, Lohnes and Handy (1968) note that the "… data are substantially in agreement with laboratory direct-shear and triaxial-shear-test results of Olsen (1958) and Akiyama (1963) for Iowa loess." Except for the Kansas and Nebraska data cited by Lohnes and Handy (1968), data for all of the other studies were known to have been used for bank-stability analyses similar to those described in this report.

Generalization of Shear Strength Data

Lohnes and Handy (1968) used the mean of their measured cohesion and friction angle value data in their slope-stability analysis of western Iowa loess. They also suggested using the mean values for design purposes. Attempts were made to group the site data in this report by stream basin, by Quarternary geology (Swinehart and others, 1994), by stratigraphy, by geographic area (proximity), and by soil groups with similar hydrologic characteristics as developed by Dugan (1984). After testing the alternatives, the sites were separated into three groups for this report based on the average mapped permeability of the 60-inch soil profile from Dugan (1984).

The permeabilities of soil in Nebraska range from less than 0.06 inches per hour (in/hr) for clay soil, to more than 16.0 in/hr for sandy soil. Dugan defined five permeability groups—group 1, less than 1.0 in/hr; group 2, 1.0 to 2.0 in/hr; group 3, 2.0 to 5.0 in/hr; group 4, 5.0 to 10.0 in/hr; and group 5, more than 10.0 in/hr. Based on Dugan's maps, permeability values of the sites in the study area ranged from groups 1 through 4, with the majority in group 2. Only two sites with acceptable BST data were in group 4, so groups 3 and 4 were combined for this report, hereafter referred to as group 3-4. Of the 908 bank sections in the study, 72 were in soil group 1, 724 were in soil group 2, and 112 were in soil group 3-4.

To evaluate whether cohesion values between each combination of groups were statistically different, two-sample t-tests were done on the rank-transformed values (Iman and Conover, 1983). Groups 1 and 2 were both statistically different from group 3-4 at an alpha of 0.010 for the two-tailed test. Groups 1 and 2 were not statistically different from each other at the same alpha; however, the ranges and median values of cohesion decreased with increasing permeability, as would be expected. The highest median cohesion was 13.6 kPa in soil group 1, with 12 BST samples from 12 sites. The median cohesion for soil group 2 was 10.8 kPa, with 119 BST samples from 98 sites. The median cohesion for soil group 3-4 was 6.7 kPa, with 19 BST samples from 18 sites. The corresponding median values of friction angle were about 26º, 28º, and 30º.

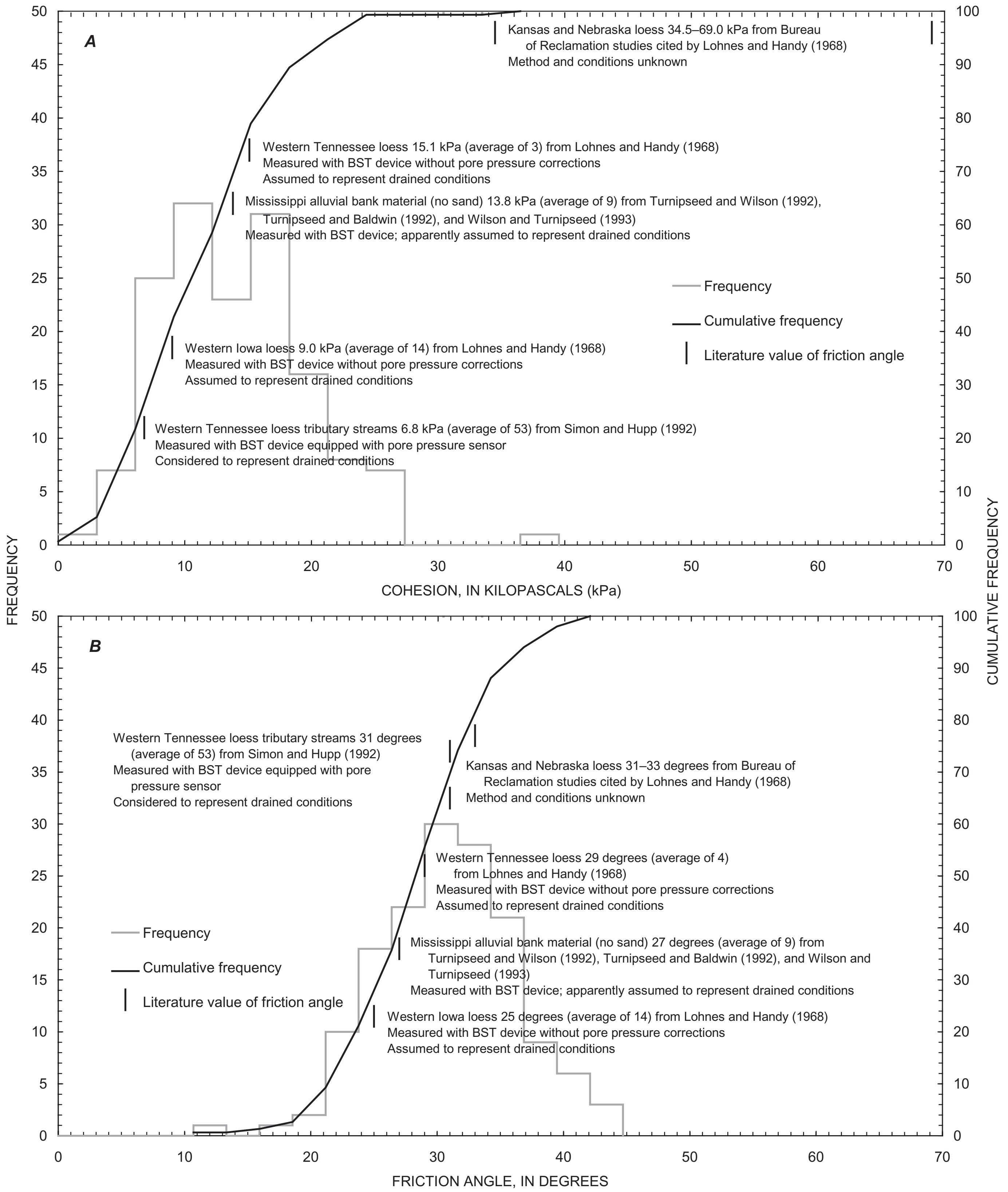


Figure 5. Distribution of soil cohesion (A) and friction angle (B) data from borehole shear tests (BSTs) in the study described in this report compared to corresponding data for loess and alluvial soils from other studies.

BANK STABILITY

Cohesive channel banks tend to fail in large blocks with material sliding along a well-defined slip surface; investigations by Simon (1989b) have shown that these mass failures generally occur during stormflow recessions when banks are saturated and the water level in the channel is relatively low so that it provides little support. According to Spangler and Handy (1973), most failures usually occur along curved rather than planar surfaces; however, evidence for bank failures along both types of failure surfaces were observed during the study described in this report. In some cases, it was evident that the failure planes had intersected vertical tension cracks running parallel to the banks. From a concurrent study of the Wehrspann watershed, within the Papillion Creek Basin, Zellars (1996) noted that "… plane failures were observed to be the dominate [dominant] failure mode." According to Thorne (1998), planar failures tend to occur more on steep banks, while failures along a curved surface (rotational failures) occur on steep and shallow banks; these statements are in agreement with the observations in this report. Some failure surfaces were accompanied by vertical sections at the top indicating the occurrence of tension cracking in conjunction with shearing along the failure surface.

Three methods were used to analyze the bank stability for this report—(1) the Culmann method (Spangler and Handy, 1973); (2) a method developed by the Agricultural Research Service (ARS) (Andrea Curini, written communication, 1999); and (3) an indirect assessment based on Bishop's simplified method of slices (Bishop, 1955) as contained in a computer program by Huang (1996)—Rotational Equilibrium Analysis of Multilayered Embankments (REAME). The Culmann and ARS methods are based on planar failures, and the indirect assessment is based on rotational failures. All three analyses required the use of the shear-strength parameters—cohesion and friction angle—and incorporate the effects of positive pore-water pressure (saturated banks) on those parameters. The ARS analysis also can incorporate the effects of negative pore-water pressure (suction) that develops as soil dries. Due to few data, all analyses were based on the assumption of homogeneous banks. The occurrence of heterogeneous banks could significantly alter the results that were obtained.

Shear Strength and Pore Pressure

The stability of a stream channel bank is based primarily on its shear strength (Spangler and Handy, 1973; Simon and Hupp, 1992). When forces acting along a potential slip surface exceed the shear strength (resisting forces) of the soil, the channel bank will fail. The Coulomb equation, modified from Spangler and Handy (1973, p. 442), expresses the shearing strength of a drained soil as the sum of the forces generated from cohesion and from normal stress (forces acting perpendicular to a potential slip surface):

$$s = c + \sigma \tan \phi \qquad (7)$$

where s is the shear strength,

c is the total or apparent cohesion (cohesive shear strength) of the soil,

σ is the total normal stress on the slip surface, and

ϕ is the internal friction angle of the soil.

Resisting forces, from friction and the interlocking of soil grains, are generated along a potential slip surface (failure plane) in proportion to the normal stress applied to the potential slip surface. The coefficient of internal friction, or friction angle, is the property of a soil that is used as the limiting value that those forces can attain. For a granular soil, this property is primarily influenced by the soil density and grain packing (Spangler and Handy, 1973, p. 434-435). The normal stress, also referred to as consolidating pressure, serves to force the soil together along the potential slip surface. For planar slip surfaces, its magnitude is determined by the weight of the material above the slip surface and the angle of the potential slip plane. The steeper the angle, the more the weight is converted to force along the slip plane (to cause failure) and the less the weight is converted to force that is normal to the slip plane (to resist failure). Cohesion represents the soil's ability to retain internally some of a previous consolidating pressure (preconsolidation) and is defined as the soil's shearing strength in the absence of any normal stress. Sand does not have this ability and is considered cohesionless.

Pore-water pressure can decrease or increase the shear strength of soil, depending on whether the pressure is positive or negative (the pore pressure from air is assumed to be negligible). Positive pore-water pressure will reduce the frictional component of shear strength, as in the adjusted Coulomb equation modified from Spangler and Handy (1973, p. 442):

$$s = c' + (\sigma - u_w)\tan\phi' \tag{8}$$

where cr is the effective cohesion of the soil,
u_w is the pore-water pressure on the slip surface, and
ϕr is the effective internal friction angle of the soil.

When pore-water pressure is negative, it will increase the cohesive shear strength as in the adjusted Coulomb equation modified from Fredlund (1987):

$$s = c' + (u_a - u_w)\tan\phi^b + (\sigma - u_a)\tan\phi' \tag{9}$$

where u_a is the pore-air pressure on the slip surface (considered negligible), and
ϕ^b is the angle used to determine the rate of increase in shear strength caused by matric suction (u_a - u_w).

Culmann Method—Planar Failure

The Culmann analysis of bank stability (Lohnes and Handy, 1968; Spangler and Handy, 1973, p. 487–490; Simon and others, 1999a, p. 125–127) is based on the assumption that failure occurs along a plane through the toe of a homogeneous bank (fig. 6). The shearing (S_s) and resisting (S_r) forces along the length (L) of a potential failure plane are determined and set equal to each other—S_s is computed from the weight of the material above the potential failure plane, and S_r is computed from equation 7 for unsaturated conditions and from equation 8 for saturated conditions. For given soil properties of friction angle and cohesion, and for a given bank slope, the maximum bank height that can be attained before failure would occur can be computed (equation modified from Lohnes and Handy, 1968, p. 249; and Spangler and Handy, 1973, p. 489):

$$H_c = \frac{4c\sin\alpha\cos\phi}{\gamma[1 - \cos(\alpha - \phi)]} \tag{10}$$

where H_c is the critical bank height at which the shearing forces equal the resisting forces, in meters,
c is the cohesion of the soil, in kilopascals,
α is the bank angle, in degrees,
ϕ is the internal friction angle of the soil, in degrees, and
γ is the unit weight of the soil, in kilonewtons per cubic meter.

For drained conditions the effective shear strength parameters, c' and ϕ', can be substituted in equation 10 for c and ϕ.

At the critical bank height, the angle of the plane at which failure would occur can be computed (equation modified from Lohnes and Handy, 1968, p. 250; and Spangler and Handy, 1973, p. 489):

$$\beta = \frac{\alpha + \phi}{2} \tag{11}$$

where β is the failure plane angle at which the shearing forces equal the resisting forces, in degrees.

Because soil is weak in tension, vertical cracks often develop on the tops of steep banks; this reduces the critical bank height that can be attained by the depth of the tension crack (equation from Simon and others, 1999a, 1999b):

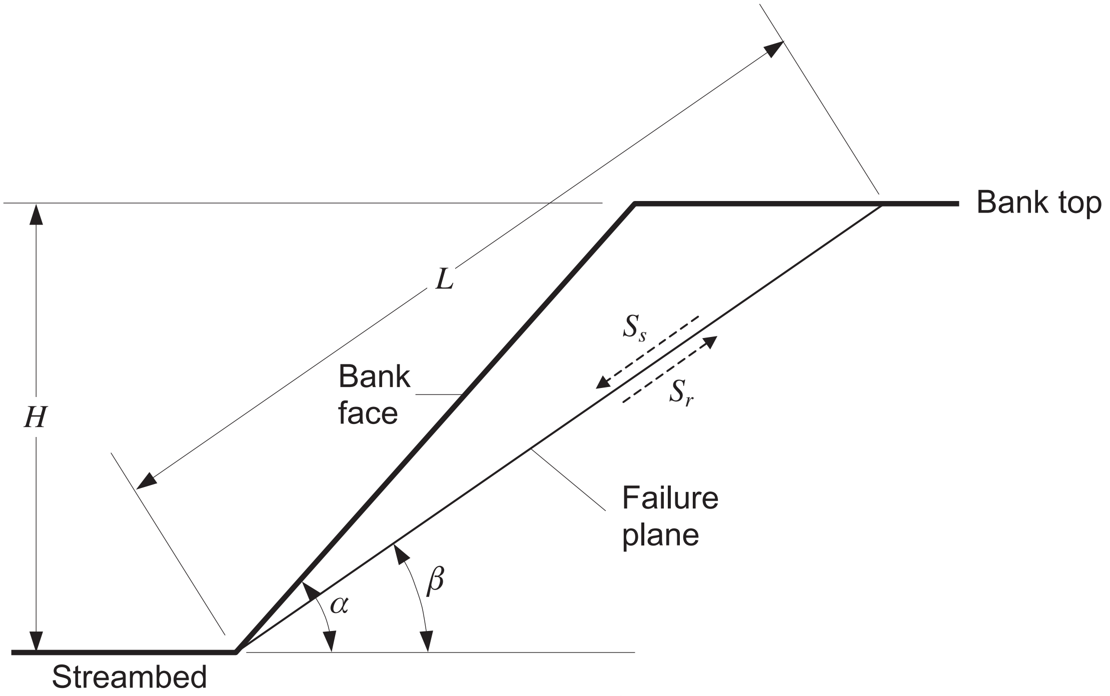
$$H_{cz} = H_c - z \tag{12}$$

where H_{cz} is the critical height of a bank with a tension crack, in meters, and
z is the depth of the tension crack, in meters.

Tension crack depth can be calculated from the properties of the soil (equation from Lohnes and Handy, 1968, p. 251; and Simon and others, 1999b, p. 140) :

$$z = \frac{2c'}{\gamma}\tan\left(45 + \frac{\phi'}{2}\right) \tag{13}$$

For saturated conditions, the friction angle is assumed to go to zero, leaving only the effective cohesion to resist failure. Therefore, the most stable bank condition



EXPLANATION

L	Failure plane length, in meters
H	Bank height, in meters
S_s	Shearing forces, in kilonewtons per meter
S_r	Resisting forces, in kilonewtons per meter
α	Bank angle, in degrees
β	Failure plane angle, in degrees

Figure 6. Conceptual diagram of a bank section and the forces acting on a potential planar failure surface that were used in the Culmann method of stability analysis.

is dry soil without tension cracks, and the least stable condition is saturated soil with tension cracks.

Approach

Two types of analyses were done for each site using the Culmann method—average bank geometry for each site with the median soil parameters from the corresponding soil group (see Generalization of Shear Strength Data section) and individual bank section geometry with soil parameters for that site. For banks that did not conform to the idealized straight-bank shape (fig. 6), average vertically weighted bank angles were used in equations 10 through 12 (see Effects of Bank Shape section).

Failure envelopes of critical bank heights and corresponding bank angles were developed from equations 10, 11, and 12 using the median shear strength and soil-unit-weight parameters for each soil group for four conditions—ambient (condition at time of sampling) and saturated soil moisture, each with and without tension cracks (figs. 7 through 9). For each tension crack condition (with and without), the ambient and saturated failure envelopes divide the plot into three areas—*stable*, *at risk*, and *unstable*. Any combination of bank angle and height below the saturated failure envelope is considered *stable*, and any point above the ambient failure envelope is considered *unstable*. Points between the two failure envelopes are considered *at risk*, meaning that the bank section is *stable* at ambient soil moisture but *unstable* if saturated. The average bank geometry (angle and height) for each site is shown on the appropriate plots to enable a visual determination of the expected stability status.

To the extent that the median parameters for the soil groups represent bank soil conditions at each site, the Culmann failure envelopes provide a general overview of the bank stability for average conditions at the sites within each of the soil groups. The proportion of *stable* sites is largest for soil group 1 (lowest permeability and highest cohesion), smallest for soil group 3-4 (highest permeability and lowest cohesion), and intermediate for soil group 2 (figs. 7 through 9).

For a given failure envelope, any one site could have individual bank sections that are more or less stable than for the average channel reach because of different bank geometry. Also, any one site could have several different failure envelopes, depending on the variability of the soil parameters at the site that could indicate more or less stable conditions than those for the median soil group values. Therefore, individual bank sections were analyzed using their specific angles and heights, and the site-specific soil parameters for the four combinations of soil moisture (ambient and saturated) and tension cracking (with and without) (table 4). These analyses assume that the few soil data for each site are representative of the whole reach that was surveyed.

As the measured bank angle (α) approaches the friction angle (ϕ), the quantity [1-cos(α–ϕ)] approaches zero and the value of critical bank height (H_c) goes to infinity in equation 10; this is illustrated by the steepening of the ambient failure envelopes as they approach the value of the friction angle (ϕ) (figs. 7 through 9). This situation resulted in some values of H_c for ambient conditions that were much larger than any known bank heights in eastern Nebraska. For practicality, any values of H_c larger than 50 meters (an arbitrary value) were listed as ">50.0" (table 4). If the measured bank angle is less than the friction angle, the failure angle (β) in equation 11 will be greater than the measured bank angle (α) and the bank should be *stable* for any bank height. Under those circumstances, however, equation 10 will still produce a finite result because the cosine of a negative angle is the same as an equal positive angle; therefore, equation 10 is not applicable and was not used. When the measured bank angle was less than the friction angle of the soil, values of H_c were listed as ">50.0" and the stability results were listed as *stable*. Neither of these situations applies for saturated conditions because the friction angle (ϕ) is assumed to be zero for that condition.

Results

Summary results for the Culmann method were compiled (table 5) and are discussed in this section. For the condition with no soil tension cracks, 611 of all 908 bank sections (67 percent) were listed as *stable* and 290 (32 percent) were *at risk*; when tension cracks were assumed, 528 bank sections (58 percent) were listed as *stable* and 367 (40 percent) were *at risk* (table 4). For soil group 1 without tension cracks, 67 of 72 bank sections (93 percent) were listed as *stable* and 5 (7 percent) were *at risk*; with tension cracks, 66 (92 percent) were listed as *stable* and 6 (8 percent) were *at risk*. For soil group 2 without tension cracks, 470 of 724 bank sections (65 percent) were listed as *stable* and 248 (34 percent) were *at risk*; with tension cracks, 402 (56 percent) were listed as *stable*, and 312 (43 percent) were *at risk*. For soil group 3-4 without tension cracks, 74 of 112 bank sections (66 percent) were listed as *stable* and 37 (33 percent) were *at risk*; with tension cracks, 60 (54 percent) were listed as *stable* and 49 (44 percent) were *at risk*. The largest percentage of *stable* banks and the smallest percentage of *at risk* banks were for soil group 1, which had the lowest soil permeability and the highest median cohesion of all the soil groups.

Theoretically, no actual bank section should fall into the *unstable* category because any such bank should have already failed. However, a few bank sections for soil groups 2 and 3-4 were listed as *unstable* based on the Culmann analysis (table 4); in actuality, these probably represent banks that are nearly unstable. For the condition without soil tension cracks, 7 of 908 bank sections (1 percent) were listed as *unstable*; none of 72 bank sections for soil group 1, 6 of 724 (1 percent) for soil group 2, and 1 of 112 (1 percent) for soil group 3-4. For the condition with tension cracks, 13 bank sections (1 percent) were listed as *unstable*; none for soil group 1, 10 (1 percent) for soil group 2 and 3 (3 percent) for soil group 3-4.

ARS Method—Planar Failure

The Agricultural Research Service (ARS) developed a method of bank stability analysis that incorporates the effects of positive and negative pore-water pressure from water in the bank, variable levels of water in the channel, and variations of bank material. Similar to the Culmann method, the forces along a

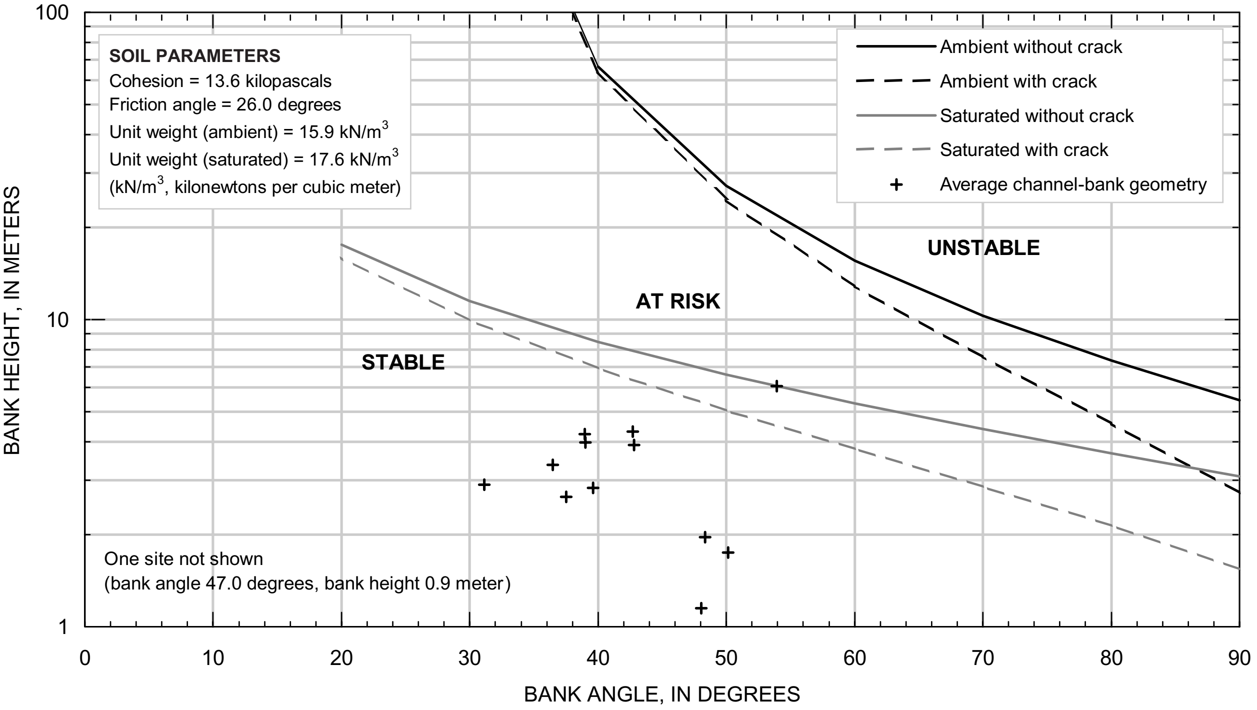


Figure 7. Culmann failure-envelope curves for soil group 1, using median soil group parameters and selected soil moisture and tension crack conditions, compared to average channel-bank geometry for sites (bank angles, weighted vertically).

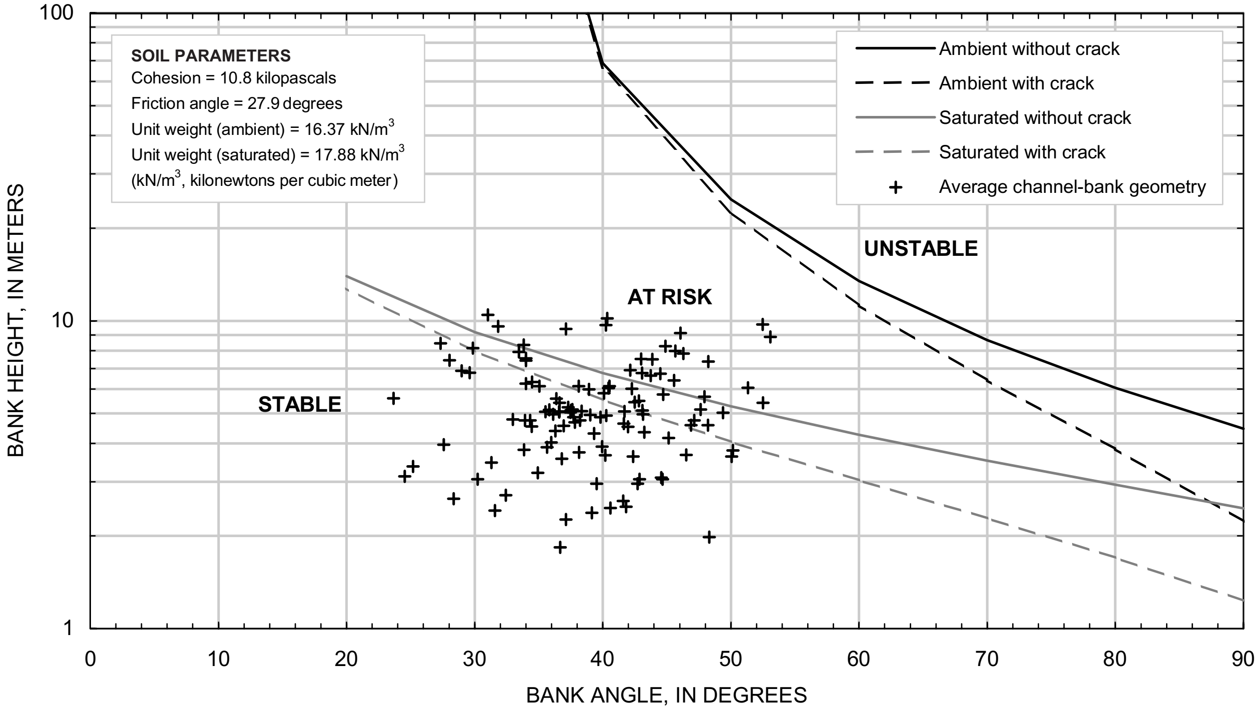


Figure 8. Culmann failure-envelope curves for soil group 2, using median soil group parameters and selected soil moisture and tension crack conditions, compared to average channel-bank geometry for sites (bank angles, weighted vertically).

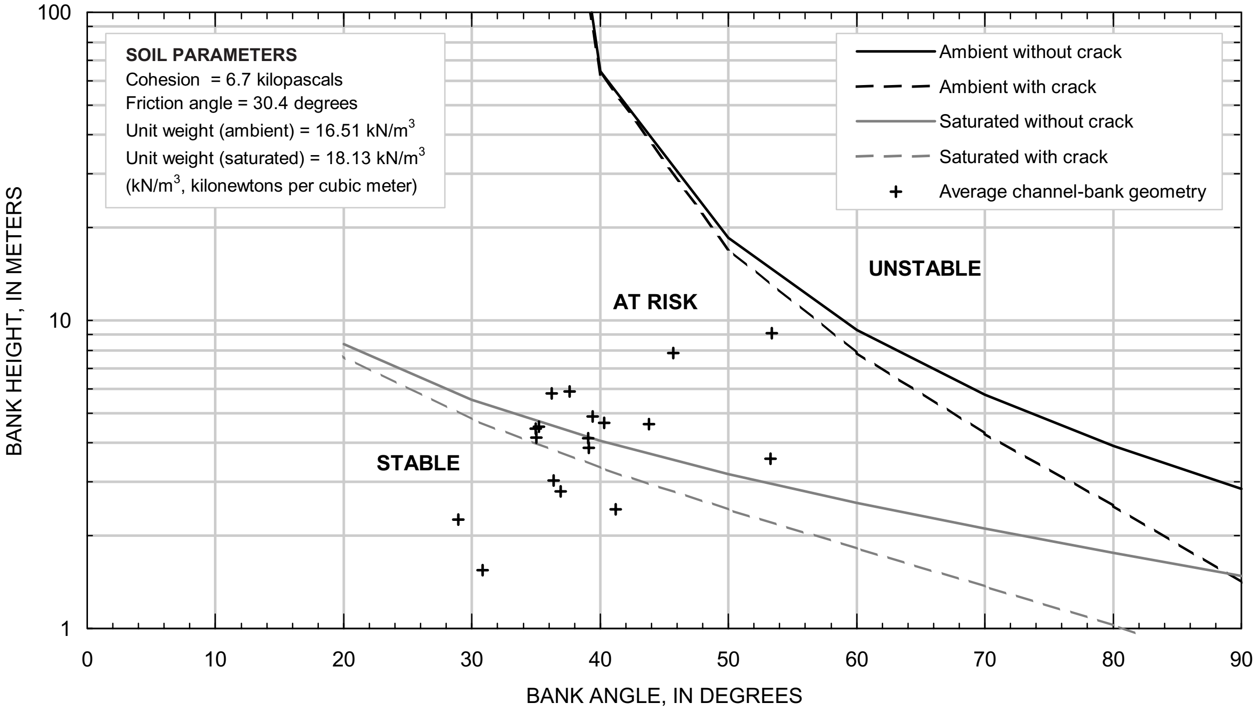
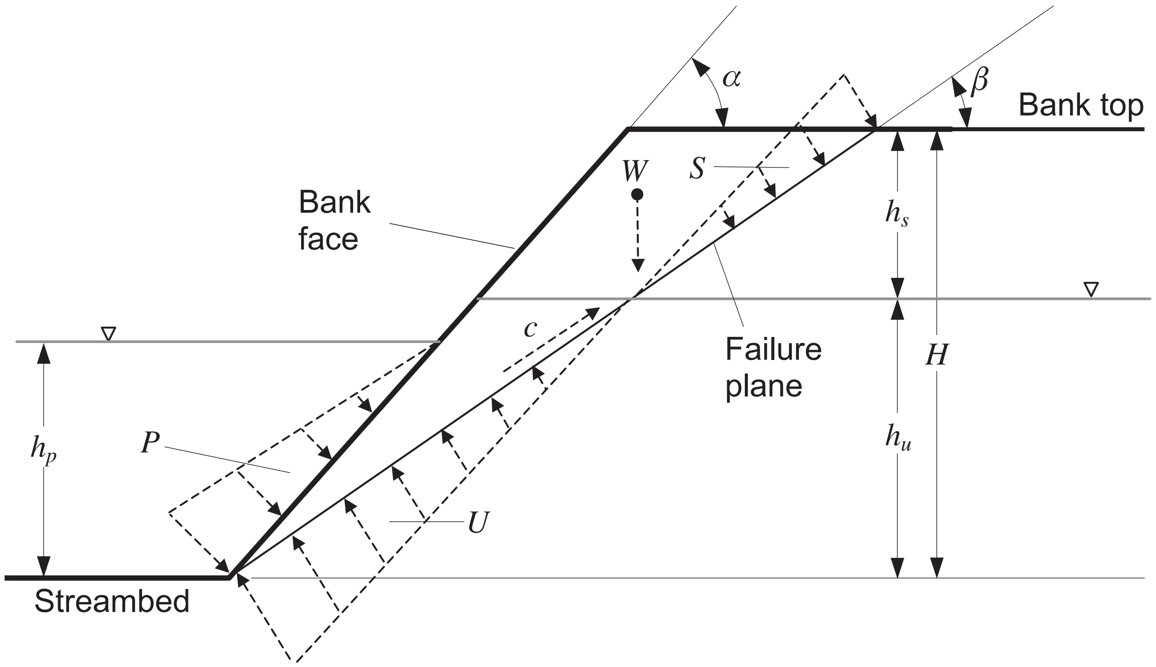


Figure 9. Culmann failure-envelope curves for soil group 3-4, using median soil group parameters and selected soil moisture and tension crack conditions, compared to average channel-bank geometry for sites (bank angles, weighted vertically).



EXPLANATION

α	Bank angle, in degrees
β	Failure plane angle, in degrees
W	Weight of failure block, in kilonewtons per meter
S	Negative pore-water pressure (suction) distribution from bank soil moisture, in kilonewtons per meter
h_s	Height of unsaturated bank above bank-water level, in meters
c	Cohesion, in kilopascals
H	Bank height, in meters
h_p	Height of channel water above streambed level, in meters
P	Hydrostatic pressure distribution from channel water, in kilonewtons per meter
U	Positive pore-water pressure distribution from bank water, in kilonewtons per meter
h_u	Height of saturated bank above streambed level, in meters; and
▽	Water surface

Figure 10. Conceptual diagram of a bank section and the forces acting on a potential planar failure surface that were used in the ARS (Agricultural Research Service) method of stability analysis.

potential failure plane are determined and summed to analyze for stability (fig.10). Several forces are accounted for differently or in addition to those in the Culmann method (Simon and others, 1999a):

1. The matric suction force (negative pore-water pressure) on the unsaturated part of the failure plane (*S*);
2. the hydrostatic-uplift force (*U*) from positive pore-water pressure in the saturated part of the failure surface; and
3. the hydrostatic-confining force from the water in the channel (*P*) (Casagli and others, 1997; Curini, 1998; Simon and Curini, 1998; and Casagli and others, 1999).

The distribution of the pore-water pressure forces is based on the position of the water table in the bank. The pressure from water in the channel serves to confine the bank and help resist failure; its computation is based on the level of the channel water. Variations in soil-bank parameters can be accounted for because the method allows the forces to be summed for various layers of soil. The ratio of the resisting forces (numerator) to the shearing or driving forces (denominator) is used to determine a factor of safety (F_S) (Simon and others, 1999a, p. 138):

$$F_S = \frac{\sum c'_i L_i + (S_i \tan\phi_i^b) + [W_i \cos\beta - U_i + P_i \cos(\alpha - \beta)] \tan\phi'_i}{\sum W_i \sin\beta - P_i \sin(\alpha - \beta)} \qquad (14)$$

where *ct* is the effective cohesion of the soil, in kilopascals,
i is the layer number,
L is the length of the failure surface, in meters,
S is the force produced by matric suction on the unsaturated part of the failure surface, in kilonewtons per meter,
ϕ^b is the angle used to determne the rate of increase in shear strength related to matric suction, in degrees,
W is the weight of the failure block, in kilonewtons per meter,
β is the failure plane angle (=1/2(α+ϕ)), in degrees,
U is the hydrostatic uplift force acting on the saturated part of the failure surface, in kilonewtons per meter,
P is the hydrostatic confining force due to external water level, in kilonewtons per meter,
α is the bank angle, in degrees, and
ϕr is the effective internal friction angle of the soil, in degrees.

A factor of safety less than 1 indicates an unstable bank and a value greater than 1 indicates a stable bank for the condition being analyzed.

As with the Culmann analysis, homogeneous banks were assumed because of the few, available soil data at each site. Therefore, only a single layer was used, and equation 14 becomes:

$$F_S = \frac{c'L + (S \tan\phi^b) + [(W \cos\beta) - U + P \cos(\alpha - \beta)] \tan\phi'}{W \sin\beta - P \sin(\alpha - \beta)} \qquad (15)$$

Approach

For each of the soil groups, bank analyses were done using a Microsoft EXCEL 2000® spreadsheet modified from A. Curini (ARS, written comm., 1999) that was developed by the ARS based on equation 15. For ϕ^b, a constant value of 17 was used based on preliminary results of other ongoing research by the ARS. Two types of analyses were done for each site using the ARS method—average bank geometry for each reach with the median soil parameters from the corresponding soil group (see preceding section, Generalization of Shear Strength Data) and individual bank section geometry with soil parameters for that site. In all cases the average bank angles were based on vertical weighting (see Effects of Bank Shape section). To compare with the Culmann analyses, banks were analyzed for the same two conditions—ambient and saturated banks with no support from channel water ($P = 0$) (table 4).

Banks were considered *unstable* if the factor of safety for the ambient condition was less than one ($F_S < 1$), and banks were considered *at risk* if the factor of safety was greater than or equal to one ($F_S \geq 1$) for the ambient condition but was less than one ($F_S < 1$) for the saturated condition. Banks were considered *stable* if the factor of safety for the saturated condition was greater than or equal to one ($F_S \geq 1$). For banks considered *at risk* additional computations were done to determine at what percentage of bank saturation (up from the toe) the factor of safety would just equal one ($F_S = 1$) (table 4); saturation above that level should result in a failure. The Solver tool in Microsoft EXCEL 2000® was used to iteratively solve equation 15 with varying levels of bank saturation until it converged on a solution. Other factors being equal, banks requiring lower percentages of bank saturation (for $F_S = 1$) will be at greater risk than those requiring higher percentages.

Results

Summary results for the ARS method were compiled (table 5) and are discussed in this section. For the ARS method, 612 of all 908 bank sections (67 percent) were listed as *stable* and 296 (33 percent) were *at risk* (table 4). For soil group 1, 67 of 72 bank sections (93 percent) were listed as *stable* and 5 (7 percent) were *at risk.* For soil group 2, 471 of 724 bank sections (65 percent) were listed as *stable* and 253 (35 percent) were *at risk.* For soil group 3-4, 74 of 112 bank sections (66 percent) were listed as *stable* and 38 (34 percent) were *at risk.* The largest percentage of *stable* banks and the smallest percentage of *at risk* banks were for soil group 1, which had the lowest soil permeability and the highest median cohesion of all the soil groups.

Unlike the Culmann analysis for ambient banks, no unstable banks ($F_S < 1$) for ambient banks were determined with the ARS analysis. This could be caused by the effects of negative pore-water pressure (suction) that are estimated in the ARS analysis, but not in the Culmann analysis. Also, there was no provision made for the adverse effects of tension cracks in the ARS analysis.

Indirect Method—Rotational Failure

An indirect method was developed to allow for rapid assessment of bank stability against rotational failure using a minimum amount of data. It is based on Bishop's simplified method of slices (Bishop, 1955), as contained in the computer program Rotational Equilibrium Analysis of Multilayered Embankments (REAME) by Huang (1996)—a DOS/Windows computer program. It was used to analyze for rotational failures in this report.

For a given bank section, REAME simulates a series of circular failure arcs of varying radii that intersect the bank section from various points of origin within a search grid specified by the user. The program automatically expands the grid, as needed, to find a point with a factor of safety less than those for surrounding points on the grid. The program then subdivides the grid around that point and searches for points with lower factors of safety; this process is repeated several times before the point with the lowest factor of safety is selected. For each trial failure arc, the assumed failure block is divided into a series of vertical slices and the forces acting on each slice are calculated. An equilibrium equation is developed from which a factor of safety is calculated. The critical slip surface is the one with the minimum factor of safety. A factor of safety of one, where the resisting forces are equal to the driving forces, indicates the threshold of bank stability. For a more thorough explanation of the theory of the simplified method of slices, the reader is referred to Huang (1996), and Fredlund and Rahardjo (1993).

Approach

Using REAME to analyze bank stability for each of the study sites would have provided results for those specific bank sections, but would not have provided a method for rapid assessment of banks to be studied in the future. Therefore, REAME was used to analyze a series of idealized straight banks (uniform slope from top-to-toe of bank) with various combinations of bank height, bank angle, and soil parameters (soil unit weight, cohesion, and friction angle) for both ambient and saturated soil moisture conditions. From these idealized straight-bank analyses, factors of safety for the actual bank sections at each of the study sites were determined by interpolation from the straight-bank analyses using the appropriate bank heights, bank angles, and soil parameters.

A uniform bank angle was needed to represent each of the actual studied sections to do the interpolation; the same would be needed for any banks to be assessed in the future. For reasons explained in a following section (Effects of Bank Shape) the average, vertically weighted angle from the top to the toe of the bank was used for this report. A Microsoft EXCEL 2000® spreadsheet, on the compact disk at the back of this report, was developed to do the five-way interpolation of the factor of safety for both ambient and saturated soil-moisture conditions.

Analyses for Idealized Straight Banks

Bank stability was evaluated for 2,100 idealized straight bank sections using REAME. For each of seven combinations of soil-moisture (ambient and saturated) and soil unit-weight (ambient:12, 15, 18, and 20 kN/m^3; saturated: 16, 18, and 20 kN/m^3), 300 analyses were done for all combinations of five soil cohesion values (0, 1, 8, 15, and 30 kPa), three soil friction angles (10^o, 25^o, and 40^o), four bank heights (1, 3, 6, and 12 m), and five bank angles (15^o, 30^o, 50^o, 70^o, and 90^o). These values cover the range of actual data for all but a relatively few of the 908 study banks.

A flat top, a uniform bank-face slope, and a flat streambed were assumed for all idealized straight bank sections. The water level in the channel was set equal to the bed level for all analyses. For the ambient soil-bank moisture condition (unsaturated bank) the water level in the bank was set equal to the water level in the channel (fig. 11B). For the saturated soil-bank moisture condition, the water level in the bank was set equal to the bank profile (fig. 12B) to simulate the worst-case condition—completely saturated banks with no support from water in the channel. To prevent evaluation of failures that intersected only the bank face or widened the bank minimally, the failure arcs were forced to intersect the top of the bank at a distance from the edge equal to at least 10 percent of the bank height. Thus, only failures that widened the bank by at least 10 percent of the bank height were evaluated. Factors of safety for each of the above conditions were calculated and compiled (table 6).

A Microsoft EXCEL 2000® spreadsheet was then developed to interpolate a factor of safety for conditions between the results obtained from the analyses for idealized straight banks. The spreadsheet contains the results shown in table 6 and uses linear interpolation, as needed, to determine the factors of safety for both ambient and saturated soil-moisture conditions from user-input soil parameters and bank geometry. Interpolation is done in the following order of parameter inputs: soil unit weight, bank height, cohesion, friction angle, and bank angle. The factor of safety is much more sensitive to changing input at low bank heights and is assumed to be less accurate than at higher bank heights because the relations are not as linear as those for soil unit weight, cohesion, and friction angle. Generally, this is not a problem, because lower banks tend to have relatively high factors of safety anyway.

Finally, the spreadsheet also estimates the maximum angle at which each bank section would be stable under both ambient and saturated soil-bank conditions with no support from water in the channel. This was done by setting the factor of safety equal to zero and inputting the known or assumed values of ambient and saturated soil unit weight, effective cohesion, friction angle, and bank height. The spreadsheet outputs the bank angles for both ambient and saturated conditions. Because it is the worst case condition, only the bank angle for the saturated soil-bank condition was reported in table 4. Actual bank angles greater than this value should be considered *at risk*. By default, the interpolation spreadsheet uses a design factor of safety of one ($F_S = 1$) to estimate the stable straight-bank angle; however, this can be reset to whatever value the user might desire to provide a margin safety.

Effects of Bank Shape

Most natural banks do not conform to the straight banks assumed for the Culmann and ARS planar-failure analyses and used for the preceding rotational-failure REAME analyses. A channel that has degraded but whose banks have not yet failed could have bank faces that project outward between the top and the toe with the steepest section nearest the toe (convex). Banks that have already failed, either by planar failure with tension cracks or by rotational failure, could have banks that project inward between the top and the toe with the steepest section nearest the top (concave). Therefore, tests were done to determine the effects that

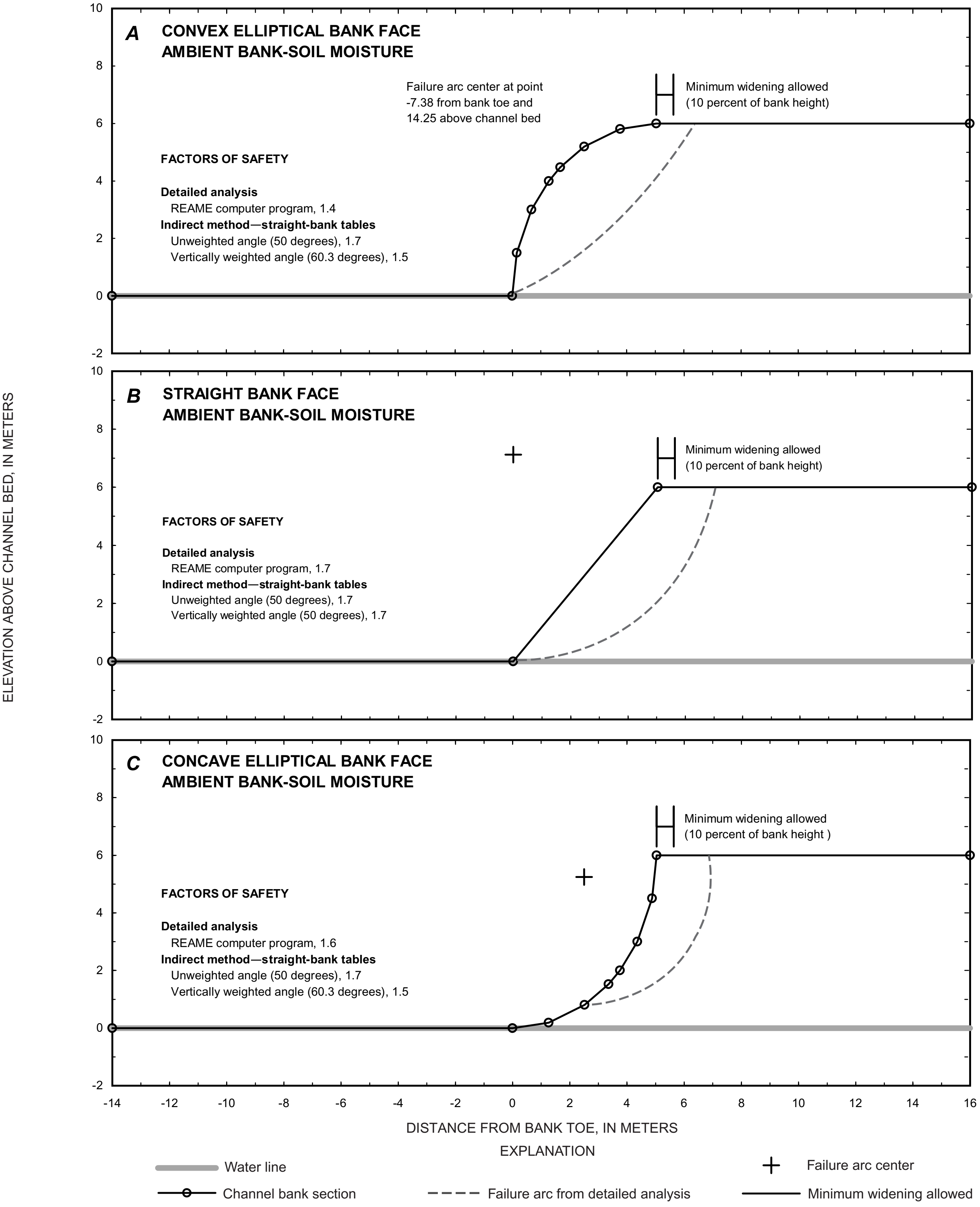


Figure 11. Example of rotational failures and minimum factors of safety for ambient (unsaturated) channel-bank sections differing only in cross-sectional shape between the top and toe—(A) convex elliptical, (B) straight, and (C) concave elliptical. Factors of safety from detailed analyses (REAME computer program and actual bank cross sections) are compared to those from the indirect method (straight-bank tables using unweighted and vertically weighted average bank angels); both are based on Bishop's simplified method of slices. Soil parameters are as follows: ambient unit weight, 15 kilonewtons per cubic meter; saturated unit weight (below the water line), 18 kilonewtons per cubic meter; cohesion, 15 kilopascals; and friction angle, 25 degrees.

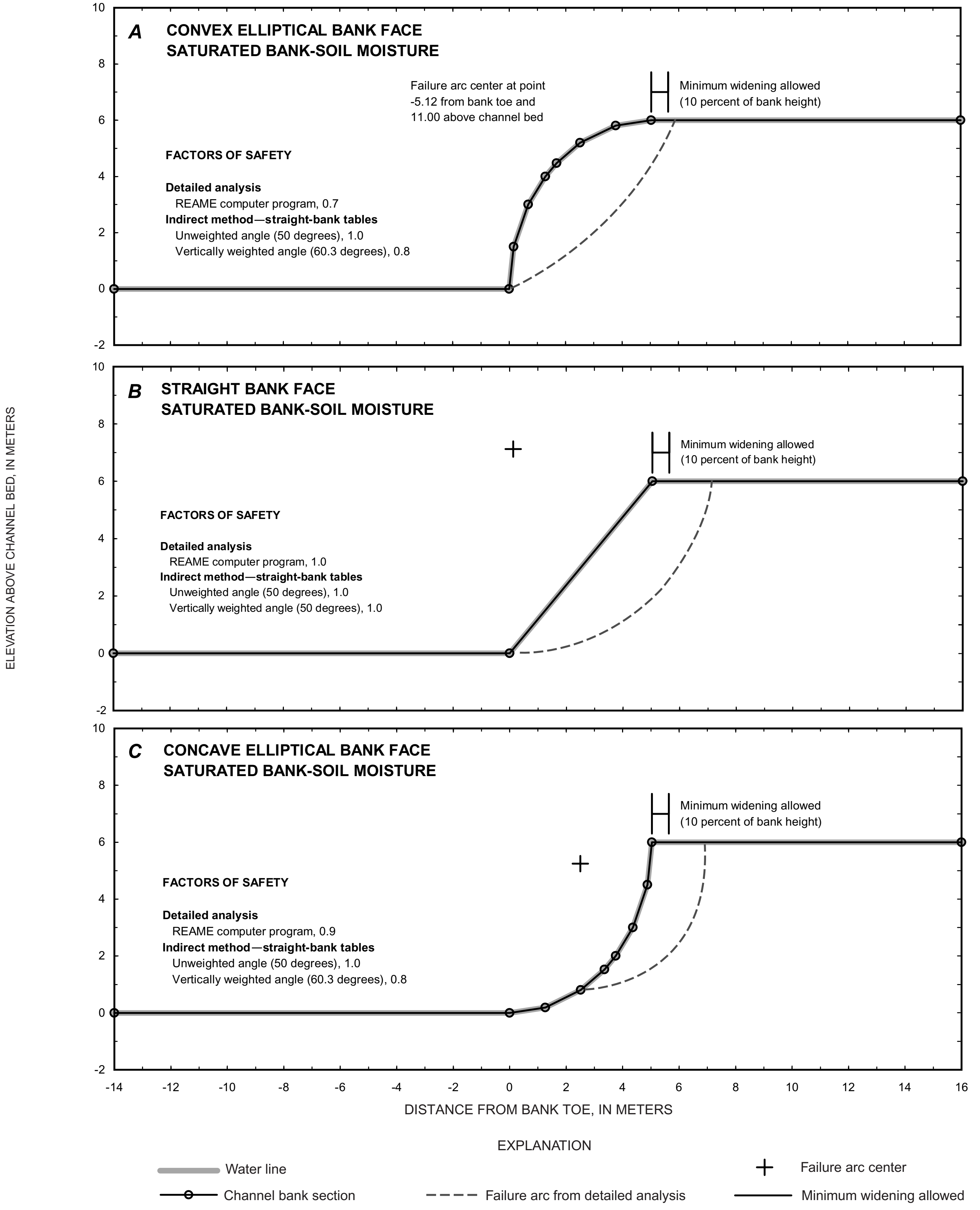


Figure 12. Example of rotational failures and minimum factors of safety for saturated channel-bank sections differing only in cross-sectional shape between the top and toe—(A) convex elliptical, (B) straight, and (C) concave elliptical. Factors of safety from detailed analyses (REAME computer program and actual bank cross sections) are compared to those from the indirect method (straight-bank tables using unweighted and vertically weighted average bank angels); both are based on Bishop's simplified method of slices. Soil parameters are as follows: saturated unit weight (below the water line), 18 kilonewtons per cubic meter; cohesion, 15 kilopascals; and friction angle, 25 degrees.

bank shape have on bank stability, compared to straight banks, and to determine how any effects might be compensated for in the various types of analyses.

A series of analyses were done for idealized straight banks, for elliptically shaped convex, and for concave banks using the REAME computer program. Standardized convex and concave banks were developed using a quarter of an ellipse, defined by six points between the top and the toe of the bank (1/4, 1/2, and 2/3 bank width; and 1/3, 1/2, and 3/4 bank height). This shape was fit to a given bank height such that angles formed by the two end points at the top and the toe (unweighted average bank angles) were the same although the shape between the endpoints was different. A detailed analysis using the REAME computer program was done on each set of banks, with all of the soil parameters being kept the same. For an example set of 6-m high, 50 degree banks, results show that convex and concave banks have reduced factors of safety compared to the straight banks for both ambient (fig. 11) and saturated (fig. 12) soil moisture. For convex banks, this can be attributed to the steepened section on the upper part of the bank, which is where the failures occurred in the examples (figs. 11 and 12).

With all other parameters unchanged, convex and concave banks had reduced factors of safety compared to straight banks for unweighted average bank angles of 15, 30, 70, and 90 degrees (fig. 13). Other sets of analyses, not shown, for other bank heights and soil conditions produced similar results. Therefore, if the indirect method is used with the unweighted average bank angle to assess natural banks with a convex or concave shape, the factors of safety will likely be overestimated.

To compensate for the effects of convex and concave bank shape when using the straight-bank tables of the indirect method, and angle larger than the unweighted bank must be used. Computing the vertically-weighted average angle from the actual bank-section data produces such a result. For straight banks, the vertically weighted angle is the same as the unweighted angle; therefore, the vertically weighted angle also can be used without affecting the results for straight banks. For the conditions given in figure 13, use of the indirect method (straight-bank tables) with vertically weighted average bank angle overcompensated for the concave banks at all bank angles, less so at the high bank angles, for both ambient and saturated conditions. For the convex banks, use of the indirect method with vertically weighted average bank angle overcompensated for bank angles less than about 45 degrees and under-compensated at bank angles higher than about 45 degrees for both ambient and saturated conditions. Analyses for other bank heights and angles, based mostly on median soil parameters, produced similar results.

A final test of the indirect method was made using actual bank-section data. Thirty bank sections were randomly selected from those used in this report. For both ambient (unsaturated) and saturated soil moisture conditions and assuming no water in the channel, detailed REAME analyses were done to determine the minimum factors of safety using site-specific data for each selected bank section. Then, using the interpolation spreadsheet, the straight-bank tables were used to compute the factors of safety for the same bank sections using both the unweighted and the vertically weighted average bank angles. Results from the indirect method for both types of average bank angles and both soil conditions were compared to the corresponding results from the detailed REAME analysis (figs. 14 and 15).

Results to the left (or above) the 1:1 reference line (figs. 14 and 15) indicate that the indirect method produces a higher factor of safety than does the corresponding REAME detailed analysis. Assuming the detailed analyses to be correct, such results mean that the indirect method indicates a more stable bank than it should. Conversely, results to the right (or below) the 1:1 reference line (figs. 14 and 15) indicate that the indirect method produces a lower factor of safety than does the corresponding REAME detailed analysis; such results mean that the indirect method indicates a less stable bank than it should. For design purposes or for purposes of identifying banks that are nearing instability, the latter type of result from the indirect method is preferable because it errs on the side of safety.

For both ambient and saturated bank soil moisture conditions, the results for the indirect method with unweighted average bank angles (figs. 14A and 15A) are, generally, to the left (or above) the 1:1 reference line. Results for the indirect method with vertically weighted average bank angles (figs. 14B and 15B) are, generally, to the right (or below) the 1:1 reference line. Therefore, it was decided to use the vertically weighted angles with the indirect method to estimate factors of safety for actual bank angles for this report to compensate for the effects of convex- and concave-shaped banks, as much as possible, without affecting results for straight banks.

Although the preceding tests for the effects of bank shape were done specifically for the indirect method and rotational failure, the rationale behind how bank shape affects stability is the same for planar failure. Therefore, because the Culmann and ARS methods also required average bank angles, vertically

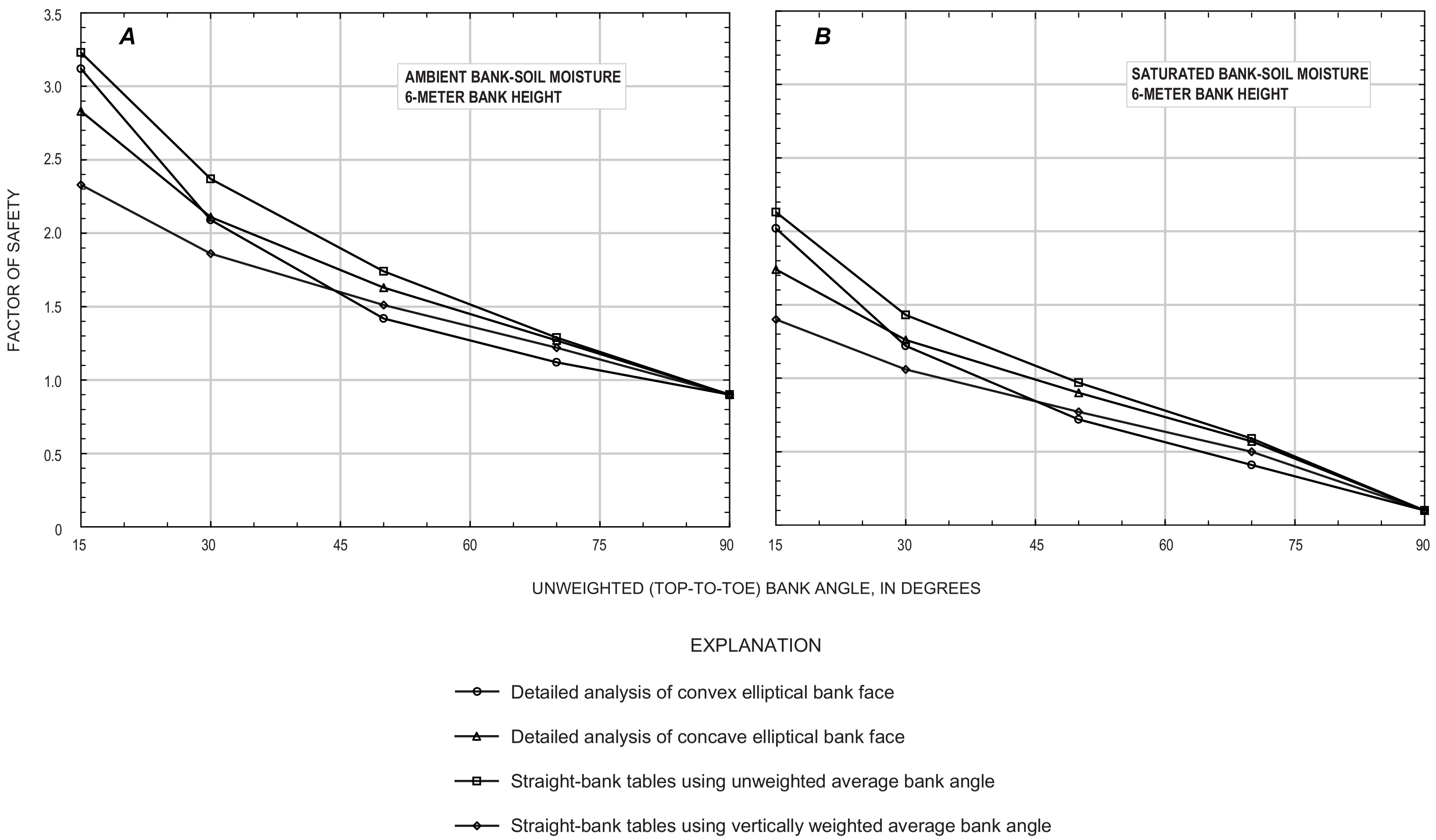


Figure 13. Example of factors of safety for (A) ambient (unsaturated) and (B) saturated elliptical (convex and concave) banks from detailed analyses (REAME computer program and actual cross sections) compared to those from the indirect method (straight-bank tables using unweighted and vertically weighted average bank angles) over a range of bank angles. Bank parameters were as follows: bank height, 6 meters; ambient soil unit weight, 15 kilonewtons per cubic meter; saturated soil unit weight, 18 kilonewtons per cubic meter; soil cohesion, 15 kilopascals; and soil friction angle, 25 degrees.

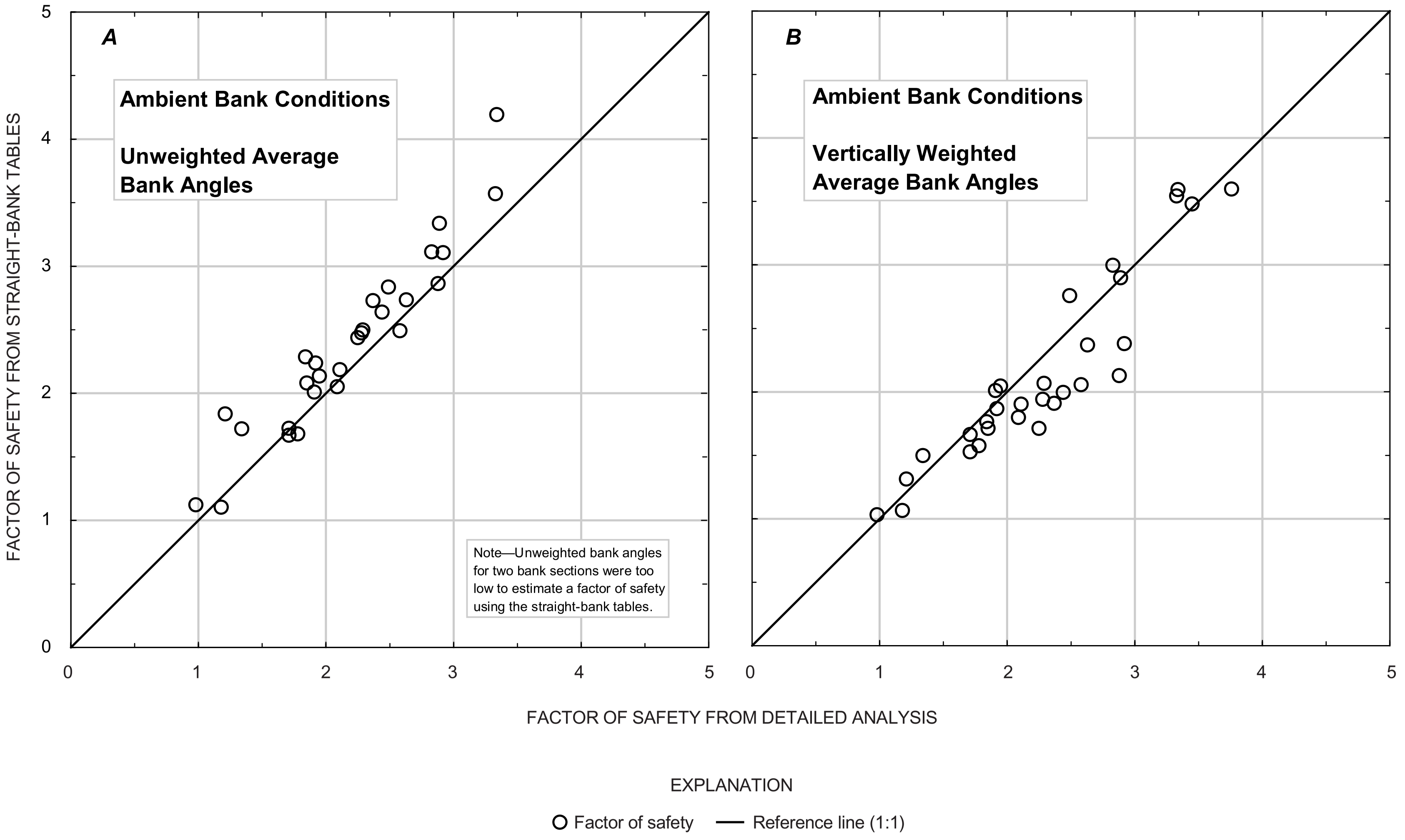


Figure 14. Factors of safety against rotational failure for 30 randomly selected bank sections under ambient (unsaturated) conditions comparing those determined from the indirect method, using the straight-bank tables with (*A*) unweighted and (*B*) vertically weighted average bank angles as inputs, to those from detailed analysis, using the REAME computer program with actual surveyed bank section points as inputs. All analyses were based on Bishop's simplified method of slices and site-specific soil data.

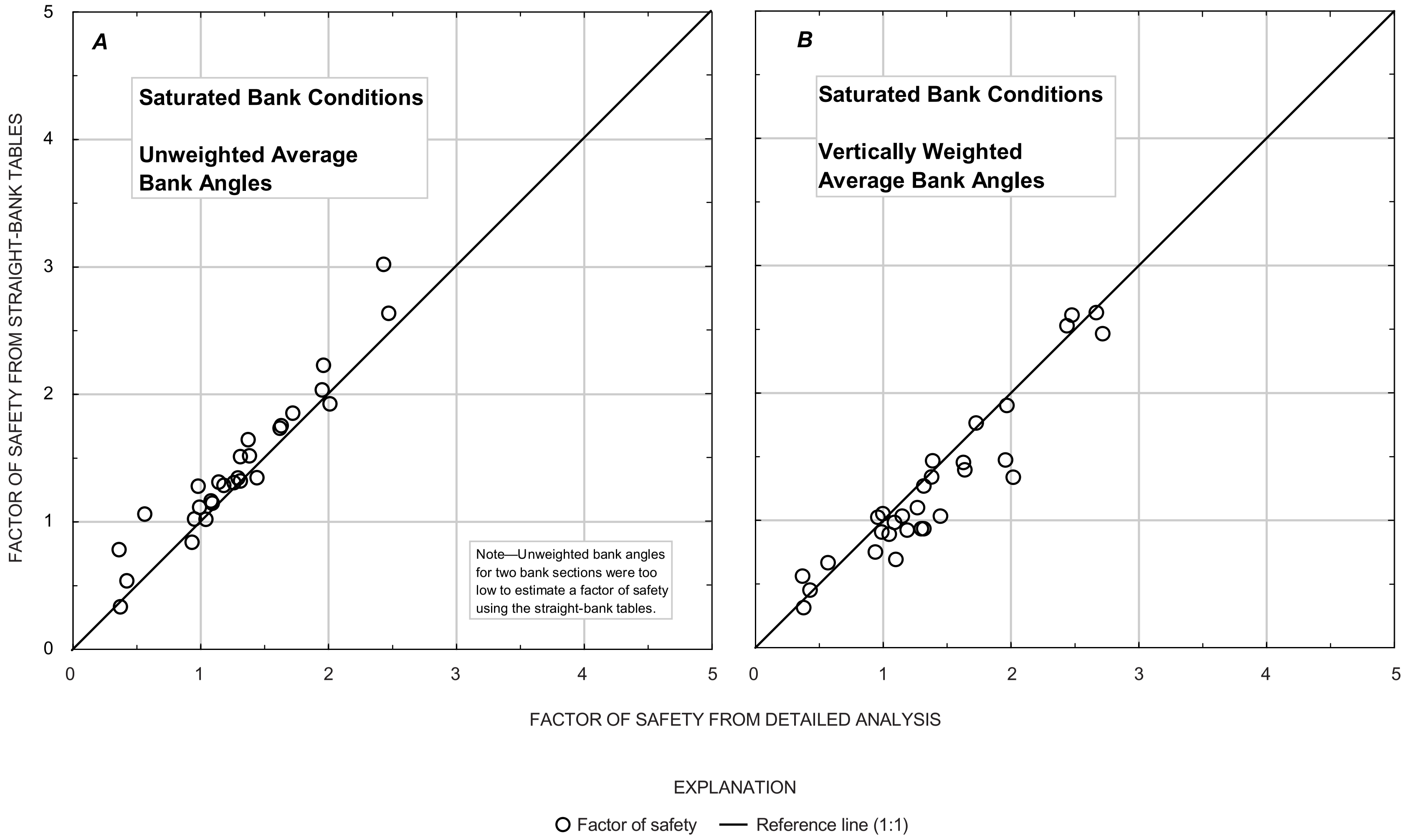


Figure 15. Factors of safety against rotational failure for 30 randomly selected bank sections under saturated conditions comparing those determined from the indirect method, using the straight-bank tables with (*A*) unweighted and (*B*) vertically weighted average bank angles as inputs, to those from detailed analysis, using the REAME computer program with actual surveyed bank section points as inputs. All analyses were based on Bishop's simplified method of slices and site-specific soil data.

weighted average bank angles were used in the analyses for planar failures as well.

Application to Studied Bank Sections

To determine factors of safety for the actual bank sections in this report using the indirect method, the spreadsheet was used to interpolate between the results obtained from the analyses for idealized straight banks. As with the Culmann and ARS methods, two types of analyses were done for each site—average bank geometry for each reach with the median soil parameters from the corresponding soil group (see preceding section, Generalization of Shear Strength Data) and individual bank section geometry with soil parameters for that site. In all cases the average bank angles were based on vertical weighting. To compare with the Culmann and ARS analyses, banks were analyzed for the same two soil moisture conditions—ambient (unsaturated) and saturated banks with no support from channel water.

Like the ARS analyses, banks were considered *unstable* if the factor of safety for the ambient condition was less than one ($F_S < 1$), and banks were considered *at risk* if the factor of safety was greater than or equal to one ($F_S \geq 1$) for the ambient condition but was less than one ($F_S < 1$) for the saturated condition. Banks were considered *stable* if the factor of safety for the saturated condition was greater than or equal to one ($F_S \geq 1$). For each average bank reach and each bank section, bank stability was classified as previously described based on factor of safety values, and the maximum stable bank angles were computed from the interpolation spreadsheet using the saturated soil parameters and the known bank heights. Results for all analyzed bank sections were compiled in table 4.

Results

Summary results for the indirect method were compiled (table 5) and are discussed next. For the indirect method, 563 of all 908 bank sections (62 percent) were listed as *stable*, 286 (31 percent) were *at risk*, and 31 (3 percent) were outside of the range of the tables developed for the method (table 4). For soil group 1, 58 of 72 bank sections (81 percent) were listed as *stable*, 6 (8 percent) were *at risk*, and 8 (11 percent) had input data out of the range of the straight-bank tables. For soil group 2, 439 of 724 bank sections (61 percent) were listed as *stable*, 247 (34 percent) were *at risk*, and 22 (3 percent) had input data out of the range of the straight-bank tables. For soil group 3-4, 66 of 112 bank sections (59 percent) were listed as *stable*, 33 (29 percent) as *at risk*, and 7 (6 percent) had input data out of the range of the straight-bank tables. The largest percentage of *stable* banks was for soil group 1, which had the lowest soil permeability and the highest median cohesion of all the soil groups.

There were 28 bank sections (3 percent) that were assessed as *unstable* ($F_S <1$ for the ambient condition; tables 4 and 5). As any *unstable* bank should have already failed, these results probably represent banks that are nearly unstable; they also are an indication of the approximate nature of the methodology and the overall conservative bias of using the vertically weighted average bank angle (see preceding section, Effects of Bank Shape). There were no bank sections that were *unstable* for soil group 1, 22 (3 percent) for soil group 2, and 6 (5 percent) for soil group 3-4.

Several banks, 31 (3 percent) were outside of the range of the tables developed for the method (tables 4 and 5). Most of the out-of-range sites had input data lower than the defined range for the bank height (less than 1 m) or bank angle (less than 15^{o}). One site, LNR-10, had a cohesion of 36.5 kPa, greater than the maximum of the range (30 kPa) of the tables. Another site, BNR-3, had a saturated soil unit weight of 18.1 kN/m^3, greater than the maximum of the range (18 kN/m^3) of the tables.

The stable bank angles computed from the straight-bank tables using the interpolation spreadsheet ($F_S =1$ for saturated banks and no channel water) were compared to the vertically weighted, average bank angles computed from the survey data. The comparison indicated that many of the surveyed bank angles were considerably less than the maximum expected stable bank angles (table 4). For severely degraded channels along straight reaches this would not be expected. As such reaches degrade, the bank heights and angles increase until the banks become *at risk* or eventually even *unstable*—at which point the bank would immediately fail; more typically the bank would become sufficiently saturated and fail before becoming *unstable*. In either case the banks would not be expected to fail well below the maximum stable angle.

For the banks with relatively low bank angles, it is possible that their channels have not yet been affected to a significant degree by degradation. Study sites were selected so that they were located throughout eastern Nebraska and throughout individual basins; this was done for the purpose of trying to develop basin-wide streambed adjustment models (Rus and others, 2003). Degradation may not yet have extended to sites along upper reaches, or lower reaches might be experiencing aggradation, which reduces a bank's height and can help to stabilize it, as degradation progresses upstream. Another possible explanation for bank angles less than the maximum stable angle is that some sections may be affected by lateral migration processes. Although efforts were made to avoid such sections, straight reaches could not always be found at the study sites. Typically along curving reaches, the bank angle on the inside bend is relatively shallow and the bank angle on the outside bend is relatively steep compared to straight reaches with similar bank material.

Another possibility is that the maximum expected stable bank angles are too steep—at least for some bank sections this is probably true. This would indicate that either the methods for analysis of bank stability are inaccurate or that the data used with the methods are not representative of actual conditions. The latter seems most likely as the methods are well established, and for the same data the results are in essential agreement. The bank geometry data were determined directly from topographic surveys and should not be a source of significant error. This leaves non-representative soil data as a probable reason for computed stable bank angles that in some cases are overly steep. Because the bank stability analyses are most sensitive to the values of soil cohesion, especially for saturated conditions, the limitations of the BSTs and the assumption of homogeneous banks are probably the main factors contributing to soil parameters that are not representative of those controlling bank stability.

The assumption of homogeneous banks was shown to be atypical, at least for those few sites for which more than one BST was made and considered useable (fig. 16). Although several sites have cohesion values that are fairly uniform, most of the sites show considerable vertical variability. The cohesion values for site MRT-10, the only site with useable BSTs at three depths, shows cohesion increasing with depth by more than 250 percent and then decreasing by more than 30 percent to the deepest test. Many of the other sites, for which only one BST was made or was useable, probably have actual variability in cohesion similar to that shown in figure 16. Horizontally, along and transverse to the banks there also may be considerable variability in cohesion.

Similar to how a weak link in a chain will determine when it fails, a weak soil area or an interface of two differing soil areas in a bank can determine where the failure plane will be and what the factor of safety might be. It is not likely that the few soil tests done at each of the sites identified the critical soil parameters needed to accurately determine bank stability or to determine the stable bank angle for each bank section. For those sites that did not have homogeneous banks and for which the critical soil parameters were not identified, the results would indicate that the banks are more stable than they really are. Although not as likely, the opposite could also be true. If a weak soil area was tested that did not extend to other bank sections the analyses for those banks would indicate less stability than might be warranted. It is apparent that more extensive soil testing than was done for this report is required before an accurate assessment of bank stability can be made at a site.

Because the BSTs require interpretation and are based on several assumptions, incorrect values of shear strength (soil cohesion and friction angle) computed from the BST measurements are possible. For example, at site BNR-7 the maximum expected stable bank angles for all sections were greater than the surveyed angles and the cohesion values for both depths tested were fairly uniform (fig. 16). However, re-interpretation of both BSTs indicated that both could have been discounted.

At least for some sites, it appears that the results of bank stability in table 4 are overly optimistic. Although some individual bank sections may be accurately portrayed, without more extensive data to determine variability or non-variability in soil shear strength, it is not known which or how many bank sections this would include.

Bank Stability Assessment at New Sites

Any of the methods demonstrated in this report can be used to make preliminary assessments of bank stability at new sites. The uncertainty in the bank stability results appears to be the result of few data on soil shear strength and the assumption of homogeneous

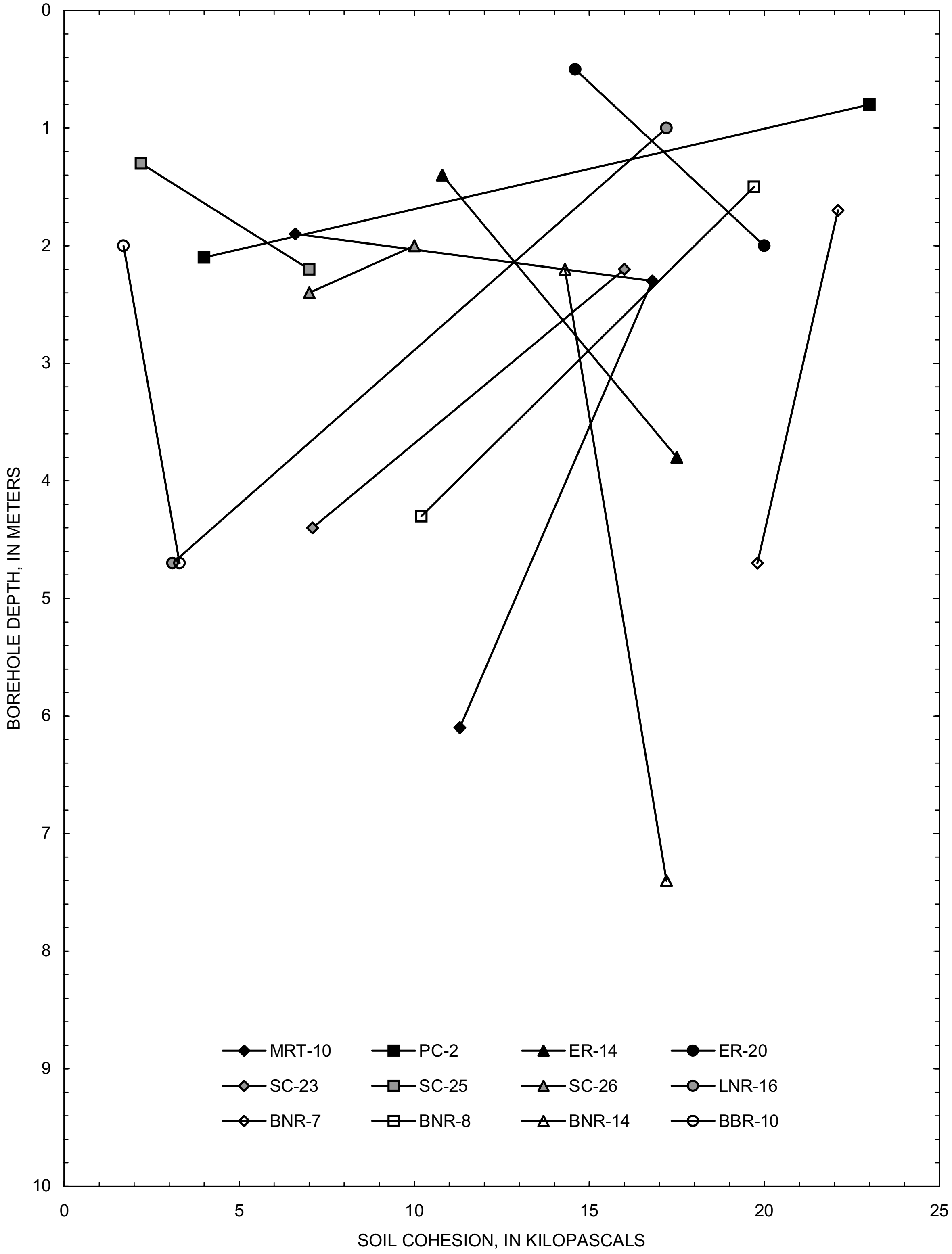


Figure 16. Soil cohesion relative to borehole depth for sites with more than one borehole shear test (BST) considered useable.

banks, not because of problems with the methods themselves. If the variability of soil parameters, especially cohesion, can be determined for a site, and if the variability is small so that average or weakest values can be used to represent the banks, the methods should be useable to make preliminary assessments of stability. If the variability is more extensive, a computer program such as REAME that can account for multiple soil types and parameters is needed.

The potential for planar failure at a bank section can be evaluated using the Culmann or ARS methods. The ARS method is still under development, and the current version of the spreadsheet and documentation would need to be obtained from ARS before using this method (Andrew Simon, National Sedimentation Laboratory, Agricultural Research Service, Oxford, Miss.). The potential for rotational failure can be evaluated using the indirect method. For preliminary assessments with either method, the user needs cross-section data and estimates of the soil parameters—cohesion, friction angle, and ambient and saturated unit weight. The vertically weighted average bank angle, or whatever average bank angle the user considers appropriate, can be computed from the cross-section data. If multiple estimates or measurements of cohesion, friction angle, and soil unit weight are made, the various combinations of parameters can be used to estimate the lowest factor of safety.

Culmann Method—Planar Failure

The critical bank height for the four conditions of ambient and saturated soil, with and without tension cracks, can be computed using equations 10, 12, and 13 with the data for the site; for saturated conditions the soil friction angle is assumed to be zero. Failure-envelope curves (figs. 7 through 9) can be developed by computing the critical bank heights for various assumed average bank angles, in addition to the actual values for the bank section being studied, and plotting the results. If the average bank angle is less than the soil friction angle, the bank should be stable and equation 10 is not applicable. The stability for saturated conditions should be less than for ambient conditions, and stability when tension cracks occur should be less than when tension cracks do not occur. These results can then be compared to the actual bank height and average bank angle to determine whether the bank is *stable*, *at risk*, or *unstable* as shown in this report.

Indirect Method—Rotational Failure

The indirect method can be used to make preliminary assessments of bank stability against rotational failure at new sites without having to run the REAME program for each new bank section. This can allow the user to separate bank sections that might require more extensive detailed analyses from those that are probably stable and should not require further study. The user can select whatever factor of safety criteria is desired to make such a separation for both ambient and saturated soil-moisture conditions. For convenience, the interpolation spreadsheet, provided on the compact disk at the back of this report, can be used to speed the interpolation process; any results appearing questionable should be checked manually against the values in table 6, which were used in the spreadsheet. When the soil and bank geometry data are entered into the interpolation spreadsheet, or when an input file is submitted with the data for multiple bank sections or combinations of soil parameters, the spreadsheet automatically computes the factor of safety for both ambient and saturated conditions for each section or combination of parameters.

In addition, the spreadsheet automatically computes the angle at which a bank section would be stable, for the given conditions of bank height and ambient and saturated soil parameters. For the latter computation, the spreadsheet uses a design factor of safety of one ($F_S = 1$) by default. However, this can be reset to whatever value the user desires. Because the interpolation spreadsheet was based on analyses of straight banks, the computed stable angle also would be for straight banks. All results from this method should be considered as preliminary assessments to be followed by more detailed analyses for any sites requiring design work or appearing to be *at risk* or nearly *unstable*.

Other Considerations

Bank sections also could be assessed under assumptions of future degradation or aggradation. For example, actual bank geometry could be artificially altered to represent a selected amount of degradation. This would change (increase) both the average bank angle and height. These assumed values can then be used in place of the actual values to plot on the failure-envelope curve (Culmann method) or to compute new factors of safety and new stable bank angles (indirect method).

For some bank sections, it may be necessary to assess the stability of part of the bank section rather than the entire section. This could be especially true for banks that are relatively high with steep upper sections and shallow slopes on the lower part. Under these conditions, the vertically weighted average angle may not represent the failure potential of the upper part of the bank. For such banks, it might be necessary to analyze only a part of the upper bank section, with corresponding changes to the average bank angle and height.

SUMMARY AND CONCLUSIONS

To alleviate frequent and prolonged flooding of fertile bottomlands, many stream channels in eastern Nebraska were dredged and straightened, beginning around the early 1900s. This practice reduced stream lengths, which increased channel gradients and stream power, and increased the ability of the flow to erode channel sediments. These modified channels have experienced streambed degradation, which has caused banks to became unstable and fail, resulting in channel widening. Degradation has progressed headward and affected the drainage systems upstream from the modified reaches.

In cooperation with local, State, and other Federal agencies, the U.S. Geological Survey began a study to characterize and analyze the stability of stream channels in eastern Nebraska. This report presents the data and summary results for the part of the study that used three methods for analyzing bank stability at selected sites in eastern Nebraska and presents a simplified method for estimating the stability of banks at new sites.

Topographic and geotechnical data were collected at approximately 150 sites among major drainage basins in 26 counties of eastern Nebraska and were selected on the basis of available historic streambed-elevation data, required for other aspects of the study. Topographic surveys to determine bank heights and angles were made upstream or downstream from bridges or culverts, primarily along straight reaches of channel to focus on bank stability related to degradation rather than to lateral stream migration. Borehole Shear Tests (BSTs) were done to determine the shear-strength properties of the banks. Soil samples were collected from the banks and were analyzed in the laboratory to determine soil unit weight, moisture content, and degree of saturation. Cumulative frequency diagrams of the cohesion and friction angle data for this report were compared to ranges of values for similar soil from other studies. Sites were separated into three soil groups based on the average mapped permeability of the 60-inch soil profile. The ranges and median values of cohesion decreased with increasing permeability, as was expected.

Three methods—Culmann, Agricultural Research Service (ARS), and an indirect assessment—were used to analyze banks for stability under both ambient (unsaturated) and saturated soil moisture conditions with no support from water in the stream channel; the latter condition represents the worst-case scenerio. Because of few data, all analyses were based on the assumption of homogeneous banks. The occurrence of heterogeneous banks could significantly alter the results that were obtained.

The Culmann and ARS methods assume failure along a linear plane (planar failure) through the toe of the bank. The Culmann method was used to determine critical bank heights above which banks would be expected to fail. These calculations were made for both presence and absence of vertical tension cracks in the top of the banks. The ARS method was used to compute a factor of safety (F_S), which is the ratio of forces resisting failure to those driving failure. The ARS method can account for positive and negative pore-water pressure from water in the banks.

The indirect assessment assumes rotational failure and is based on Bishop's simplified method of slices as contained in the computer program Rotational Equilibrium Analysis of Multilayered Embankments (REAME). Factors of safety were computed for 2,100 idealized, uniform-angle (straight) banks for all combinations of 7 soil unit weights (4 ambient and 3 saturated), 5 cohesions, 3 soil friction angles, 4 bank heights, and 5 bank angles. Factors of safety for the studied banks were then estimated from the results for the idealized straight banks by interpolation. A Microsoft EXCEL 2000® spreadsheet, included on a compact disk at the back of this report, was developed for the factor-of-safety interpolation and to estimate the stable bank angle for given soil conditions and a desired factor of safety. Because most natural banks do not conform to the idealized straight banks assumed for the three methods, a series of analyses was done to test for the effects of bank shape. It was found that the average, vertically weighted bank angle approximately compensates for the effects of convex and concave bank shape without affecting the results for straight banks. An additional test of the indirect method was made by comparing results to those computed from detailed REAME analyses using actual cross-section data. For both ambient and saturated bank soil, factors of safety for unweighted average bank angles were, generally, overestimated compared to the detailed REAME analyses. Conversely, the factors of safety for vertically weighted average bank angles were, generally, underestimated compared to those for the detailed REAME analyses. The latter is preferable because it errs on the side of safety.

For each average bank reach and each bank section, the maximum expected stable bank angles were computed from the interpolation spreadsheet using the saturated soil parameters, the known bank heights, and a factor of safety of one. A bank was considered *stable* if the critical bank height was greater than the actual bank height or if the factor of safety was greater than or equal to one for the saturated soil-moisture condition. A bank was considered *at risk* if the critical bank height was greater than the actual bank height or if the factor of safety was greater than or equal to one for the ambient condition, but not for the saturated condition, meaning that the bank should fail when it becomes saturated. A bank was considered *unstable* if the critical bank height was less than the actual bank height or if the factor of safety was less than one for the ambient soil-moisture condition; theoretically, any such bank should have already failed. Results indicated that the three methods were in essential agreement with about two thirds of the sections classified as *stable* and less than one third classified as *at risk* unless tension cracks were assumed, then the *at risk* category increased to about 40 percent. For each of the methods, the largest percentage of *stable* banks and the smallest percentage of *at risk* banks was for soil group 1, which had the lowest soil permeability and the highest median cohesion of the three soil groups.

The stable bank angles computed from the straight-bank tables using the interpolation spreadsheet (F_S =1 for saturated banks and no channel water) were compared to the vertically weighted, average bank angles computed from the survey data. The comparison indicated that many of the surveyed bank angles were considerably less than the expected stable bank angles. For severely degraded channels along straight reaches this was not expected. As such reaches degrade, the bank heights and angles increase until the banks become *at risk* or eventually even *unstable*—at which point the bank would immediately fail; more typically the bank would become sufficiently saturated and fail before becoming *unstable*. In either case the banks would not be expected to fail well below the maximum stable angle.

For the banks with relatively low bank angles, it is possible that their channels have yet to be affected to a significant degree by degradation. Study sites were selected so that they were located throughout individual basins for the purpose of trying to develop basin-wide streambed adjustment models. As such, degradation may not yet have extended to sites along upper reaches, or, lower reaches might be experiencing aggradation as degradation moves upstream—this can help to stabilize bank sections by reducing height. Another possible explanation for bank angles less than the maximum stable angle is that some sections may be affected by lateral migration processes. Although efforts were made to avoid such sections, straight reaches could not always be found at the study sites. Typically along curving reaches, the bank angle on the inside bend is relatively shallow and the bank angle on the outside bend is relatively steep compared to straight reaches with similar bank material.

Another possibility is that the maximum expected stable bank angles are too steep. At least for some bank sections this is probably true and would seem to indicate that either the bank-stability methods were flawed or that the data used were not representative of actual bank conditions. The latter seems most likely as the methods are well established, and for the same data, the results are in essential agreement. The bank geometry data were determined directly from topographic surveys and should not be a source of significant error. This left non-representative soil data as a probable reason for computed stable bank angles that, at least in some cases, were overly steep. Because the bank stability analyses are most sensitive to the values of soil cohesion, especially for saturated conditions, the limitations of the BSTs and the assumption of homogeneous banks were probably the main factors contributing to soil properties that were not representative of those controlling bank stability.

The assumption of homogeneous banks was determined to be atypical. Examination of the cohesion values compared to borehole/sample depth indicated considerable vertical variability for most sites with more than one useable BST. The potential for horizontal variability within a reach was indicated by the considerable variability in cohesion from site to site. A weak soil area or an interface of two differing soil areas in a bank can determine where the failure plane will be and what the factor of safety might be; therefore, it is not likely that the few soil tests done at each of the sites identified the critical soil parameters needed to accurately assess bank stability or to determine the expected stable bank angle for each bank section. Because BSTs require interpretation, there also exists the possibility of misinterpretation, which can result in incorrect values of shear strength (soil cohesion and friction angle) being computed from the BST measurements. At least for some bank sections, it appeared that the summary results of bank stability were overly optimistic. Although some individual bank sections may be accurately portrayed, without more extensive data to determine variability or non-variability in soil shear strength, it is not known which or how many bank sections this would include.

If the variability of soil parameters, especially cohesion, can be determined for a site, and if the variability is small so that average or weakest values can be used to represent the banks, any of the methods demonstrated in this report can be used to make preliminary assessments of channel bank stability at new sites. Critical bank height for the four conditions of ambient and saturated soil, with and without tension cracks, can be computed using the equations for planar failures listed in the Culmann method. Results can then be compared to the actual bank height to determine whether the bank is *stable*, *at risk*, or *unstable*. The potential for rotational failure at a bank section can be evaluated using the interpolation spreadsheet from the indirect method to estimate the factor of safety for both ambient and saturated soil-moisture conditions. In addition, the spreadsheet automatically computes the angles at which the bank section would be stable for the given bank height and soil parameters. Either method also could be used to assess future bank stability under assumptions of degradation by simply altering actual bank geometry and re-evaluating. For sites with extensive variability in soil shear-strength, a method needs to be used that that can account for multiple soil areas with differing parameters.

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SUPPLEMENTAL DATA

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999

[ID, identification; NDOR, Nebraska Department of Roads; No., number; Cr, Creek; N#, Nebraska State route; Nebr, Nebraska; W, west; US#, U.S. route; CR, County Road; Co, County; sec, section; T#X, township; N, north; R#X, range; E, east; NW, northwest; SE, southeast; S, south; St, Street; Rd, Road; Br, Branch; trib, tributary; L#X, State connecting link; Ave, Avenue; S#X, State spur; R, River; M, Middle; Fk, Fork; SW, southwest]

			Bank material			
Site ID	**Station name[1]**	**NDOR bridge ID**	**No. of samples analyzed for soil unit weight**	**No. of samples analyzed for particle size**	**No. of samples analyzed for Atterburg limits**	**Soil group[2]**
		Missouri River Tributary Basins				
MRT-1	Bow Cr at N84	S084 04362	1	1	0	2
MRT-2	Bow Cr at N12 Bow Cr at St. James, Nebr 06478518)	S012 20744	1	1	1	2
MRT-3	W Bow Cr at US81	S081 20306	1	0	0	2
MRT-4	Aowa Cr at CR, Dixon Co (near center sec 1, T30N, R5E)	C026 22325P	1	1	0	2
MRT-5	South Cr at CR, Dakota Co (NW1/4 sec 10, T29N, R5E)	C026 13020	1	1	0	2
MRT-6	Aowa Cr at N12	S012 23427	1	0	0	2
MRT-7	Otter Cr at CR, Dixon Co (SE1/4 sec33, T29N, R6E)	C026 13810P	1	0	0	2
MRT-8	Elk Cr at US20	S020 42270	1	1	0	2
MRT-9	S Omaha Cr at N94 (S Omaha Cr at Walthill, Nebr 06600900)	S094 01301	2	2	1	2
MRT-10	Omaha Cr at Main St, Homer (Omaha Cr at Homer, Nebr 06601000)	C022 23015	3	2	1	2
MRT-11	Elm Cr at US75	S075 14855	1	1	0	1
MRT-12a	New York Cr at New York Cr Rd, Washington Co (New York Cr east of Spiker, Nebr 06608900)	C089 21910P	0	0	0	2
MRT-12b	New York Cr at CR21, Washington Co	unknown	1	1	0	2
MRT-13	Weeping Water Cr at N1	S001 00266	1	1	0	2
MRT-14	Weeping Water Cr at CR, Cass Co (Weeping Water Cr at Weeping Water, Nebr 06806460)	C013 13710P	1	0	0	2
MRT-15	S Br Weeping Water Cr at N67	S067 06587	1	0	0	2
MRT-16	Weeping Water Cr at US75 (Weeping Water Cr at Union, Nebr 06806500)	S075 05774	2	2	0	2
MRT-17	Honey Cr at N67	S067 02402	1	1	1	2

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999—Continued

			Bank material			
Site ID	**Station name[a]**	**NDOR bridge ID**	**No. of samples analyzed for soil unit weight**	**No. of samples analyzed for particle size**	**No. of samples analyzed for Atterburg limits**	**Soil group[b]**
		Papillion Creek Basin				
PC-1	N Br W Papillion Cr at Fort St, Douglas Co	C028 21415	2	2	1	2
PC-2	N Br W Papillion Cr at Blondo St, Douglas Co	C028 21820	3	3	1	2
PC-3	W Papillion Cr at US275	S275 17757	1	0	0	2
PC-4	S Papillion Cr trib at Cornhusker Rd, Sarpy Co	C077 20620	1	0	0	2
PC-5	W Papillion Cr at Giles Rd, Sarpy Co	C077 20435	1	1	0	2
PC-6	Big Papillion Cr at 168th St, Douglas Co	C028 13140	1	1	0	2
PC-7	Big Papillion Cr at Fort St, Omaha	C028 21420	1	0	0	2
PC-8	Eagle Run at 120th St, Omaha	C028 13910	1	0	0	2
PC-9	Little Papillion Cr at L28K	SL28K 01578	1	1	0	2
PC-10	Cole Cr at Ames Ave, Omaha	C028 F1405	1	1	0	2
PC-11	Cole Cr at Blondo St, Omaha	C028 31835	1	0	0	2
PC-12	Papillion Cr at Capeheart Rd, Bellevue	C077 01205P	1	1	0	2
		Platte River Tributary Basins				
PRT-1	Shell Cr at CR, Platte Co (SW1/4 sec 14, T18N, R1E) (Shell Cr near Columbus, Nebr 06795500)	C071 05705P	1	1	0	2
PRT-2	Shell Cr at US30	S030 39774	1	1	0	2
PRT-3	Bone Cr at S12B	SS12B 00427	1	1	0	2
PRT-4	Bone Cr at N15	S015 09916	1	1	0	2
PRT-5	Skull Cr at CR, Butler Co (sec 22/27, T16N, R4E)	C012 32035	1	1	0	3
PRT-6	Skull Cr at S12A	SS12A 00554	1	1	0	3
PRT-7	Otoe Cr at US77	S077 10726	1	1	0	1
PRT-8	Otoe Cr at S78J	SS78J 00074	1	0	0	1
PRT-9	Buffalo Cr trib at 192nd St, Sarpy Co	C077 11310	1	0	0	2
PRT-10	Buffalo Cr at N50	S050 07970	1	1	1	2
PRT-11	Springfield Cr at Platteview Rd, Sarpy Co	C077 11640	1	0	0	2
PRT-12	Fourmile Cr at N66	S066 10234	1	1	0	2
PRT-13	Fourmile Cr at Bay Rd, Cass Co	C013 00415	1	0	0	2

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999—Continued

Site ID	Station name[a]	NDOR bridge ID	Bank material: No. of samples analyzed for soil unit weight	Bank material: No. of samples analyzed for particle size	Bank material: No. of samples analyzed for Atterburg limits	Bank material: Soil group[b]
		Elkhorn River Basin				
ER-1	Elkhorn R at US81 (Elkhorn R at Norfolk, Nebr 06799000)	S081 15491	0	0	0	4
ER-2	Union Cr at Main St (old US81), Madison (Union Cr at Madison, Nebr 06799230)	C059 H3905	1	1	1	3
ER-3	Union Cr at CR, Stanton Co (SE1/4 sec 15, T22N, R1E)	C084 13205	1	0	0	3
ER-4	Plum Cr at N15	S015 15738	1	0	0	2
ER-5	Plum Cr at N51	S051 00598	1	1	0	2
ER-6	Elkhorn R at N32 (Elkhorn R at West Point, Nebr 06799350)	S032 07316	1	1	0	4
ER-7	Pebble Cr at N32	S032 06215	2	1	0	2
ER-8	Pebble Cr at N91	S091 19072	1	0	0	4
ER-9	Pebble Cr at CR "G", Dodge Co (Pebble Cr at Scribner, Nebr 06799385)	C027 02305P	1	1	1	2
ER-10	M Logan Cr at N57	S057 05119	1	1	0	2
ER-11	Deer Cr at N57	S057 04075	1	1	1	2
ER-12	S Logan Cr at N15	S015 16384	1	1	0	2
ER-13	Logan Cr at N35	S035 04053	1	0	0	2
ER-14	Logan Cr at N94 (Logan Cr at Pender, Nebr 06799450)	S094 00025	2	2	0	2
ER-15	Logan Cr at CR 22, Dodge Co (Logan Cr near Uehling, Nebr 06799500)	C027 30645	2	2	0	2
ER-16	W Fk Maple Cr at N91	S091 17273	1	1	0	2
ER-17	Dry Cr at N15	S015 11596	1	1	1	2
ER-18	E Fk Maple Cr at N91	S091 17846	1	0	0	2
ER-19	Maple Cr at N79	S079 05122	1	0	0	2
ER-20	Maple Cr at CR20, Dodge Co (Maple Cr near Nickerson, Nebr 06800000)	C027 13910	2	2	0	2
ER-21	Maple Cr at US77 (former site of Maple Cr near Nickerson, Nebr 06800000)	S077 12173	0	0	0	2
ER-22	Bell Cr at N32	S032 09289	1	1	0	2

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999—Continued

Site ID	Station name[a]	NDOR bridge ID	Bank material			
			No. of samples analyzed for soil unit weight	No. of samples analyzed for particle size	No. of samples analyzed for Atterburg limits	Soil group[b]
	Elkhorn River Basin—Continued					
ER-23	Little Bell Cr at CR P11, Washington Co	C089 01130	1	0	0	2
ER-24	Bell Cr at CR 26, Washington Co	C089 02610	1	1	0	2
ER-25	Elkhorn R at N64 (Elkhorn R at Waterloo, Nebr 06800500)	S064 06033	2	2	0	4
	Salt Creek Basin					
SC-1	Olive Br at SW 86th St, Lancaster Co	C055 00910	1	1	0	2
SC-2	Hickman Br at S 110th St, Lancaster Co	C055 03705	1	0	0	2
SC-3	Salt Cr at S55F (Salt Cr at Roca, Nebr 06803000)	SS55F 00229	2	2	1	2
SC-4	Beal Slough at N2	S002 46092	1	1	0	2
SC-5	Haines Br at Midway Rd, Lancaster Co	C055 04405P	1	0	0	2
SC-6	S Br Middle Cr at SW 126th St, Lancaster Co	C055 60315	1	1	0	2
SC-7	Middle Cr at US6	S006 30732	1	0	0	2
SC-8	Middle Cr at SW 40th St, Lancaster Co (Middle Cr at SW 40th St at Lincoln, Nebr 06803170)	C055 31520	1	0	0	2
SC-9	Oak Cr at N66	S066 05451	1	1	0	2
SC-10	N Oak Cr at N66	S066 06060	1	0	0	2
SC-11	Oak Cr at US34	S034 31754	1	1	0	2
SC-12	W Oak Cr at US34	S034 31644	1	0	0	2
SC-13	Salt Cr at N 27th St, Lincoln (Salt Cr at Lincoln, Nebr 06803500)	C055 22535	1	1	0	2
SC-14	Little Salt Cr at Davey Rd, Lancaster Co	unknown/Culvert	1	1	1	1
SC-15	Little Salt Cr at Branched Oak Rd, Lancaster Co	C055 11215	1	0	0	1
SC-16	Little Salt Cr at NW 12th St, Lancaster Co	C055 41935	1	1	0	2
SC-17	Deer Cr at Davey Rd, Lancaster Co	C055 21013	3	1	1	1
SC-18	Deer Cr at Branched Oak Rd, Lancaster Co	C055 11220	1	1	0	1
SC-19	Little Salt Cr at Raymond Rd, Lancaster Co	C055 11415	1	1	1	1
SC-20	Little Salt Cr at Waverly Rd, Lancaster Co	C055 01815	2	1	1	2
SC-21	Little Salt Cr at Arbor Rd, Lancaster Co (Little Salt Cr near Lincoln, Nebr 06803510)	C055 02205P	4	1	0	2

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999—Continued

Site ID	Station name[a]	NDOR bridge ID	Bank material			
			No. of samples analyzed for soil unit weight	No. of samples analyzed for particle size	No. of samples analyzed for Atterburg limits	Soil group[b]
	Salt Creek Basin—Continued					
SC-22	Salt Cr at 70th St, Lincoln (Salt Cr at 70th St at Lincoln, Nebr 06803513)	C055 13120	1	1	1	2
SC-23	Stevens Cr at Havelock Ave, Lancaster Co (Stevens Cr near Lincoln, Nebr 06803520)	C055 32815	2	2	1	2
SC-24	Rock Cr at Ashland Rd, Lancaster/Saunders Co	C055 10230	1	0	0	2
SC-25	Rock Cr at Agnew Rd, Lancaster Co (Rock Cr near Ceresco, Nebr 06803530)	C055 00650	2	2	0	2
SC-26	Salt Cr at CR, Cass Co (Salt Cr at Greenwood, Nebr 06803555)	C013 01405P	2	1	1	2
SC-27	N Fk Wahoo Cr at N79	S079 02719	1	0	0	2
SC-28	N Fk Wahoo Cr at N92	S092 44217	1	1	0	2
SC-29	Cottonwood Cr trib at CR "S" 2200, Butler Co (Cottonwood Cr trib above Dam 6B near Prague, Nebr 06803935)	C078 01805	1	1	1	1
SC-30	Cottonwood Cr at S78E	SS78E 00387	1	0	0	2
SC-31	Sand Cr trib at CR 24, Saunders Co	C078 11765	1	0	0	3
SC-32	Sand Cr at CR 22, Saunders Co	C078 22150	1	1	0	3
SC-33	Wahoo Cr at N63 (Wahoo Cr at Ithaca, Nebr 06804000)	S063 03460	2	1	1	2
SC-34	Johnson Cr at CR G, Saunders Co (Johnson Cr near Memphis, Nebr 06804900)	C078 24260	1	0	0	2
	Little Nemaha River Basin					
LNR-1	Little Nemaha R at N43	S043 01441	1	0	0	2
LNR-2	Silver Cr at S66A	SS66A 00269	1	0	0	2
LNR-3	Hooper Cr at N43	S043 02621	1	1	0	2
LNR-4	Hooper Cr at N2	S002 48008	1	0	0	2
LNR-5	Little Nemaha R at N50 (Little Nemaha R near Syracuse, Nebr 06810500)	S050 05049	0	0	0	2
LNR-6	Muddy Cr at CR "O", Otoe Co	C066 13035	1	1	0	2
LNR-7	S Fk Little Nemaha at CR "N", Otoe Co	C066 02810	1	1	0	2

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999—Continued

			Bank material			
Site ID	Station name[a]	NDOR bridge ID	No. of samples analyzed for soil unit weight	No. of samples analyzed for particle size	No. of samples analyzed for Atterburg limits	Soil group[b]
	Little Nemaha River Basin—Continued					
LNR-8	S Fk Little Nemaha R at N50	S050 04149	1	0	0	2
LNR-9	Coon Cr at N50	S050 03929	1	0	0	1
LNR-10	Spring Cr at US136	S136 21474	1	0	0	1
LNR-11	Spring Cr at CR, Johnson Co (sec 5/8, T6N, R12E)	C049 10445	1	1	0	2
LNR-12	N Fk Little Nemaha at N50	S050 05900	1	0	0	2
LNR-13	N Fk Little Nemaha at CR "L", Otoe Co	S002 49685	1	0	0	2
LNR-14	Little Nemaha R at N67 near Talmage	S067 04771	2	0	0	2
LNR-15	Rock Cr at N128	S128 01489	1	0	0	2
LNR-16	Rock Cr at N67	S067 03578	2	2	1	2
LNR-17	Little Nemaha R at US136 (Little Nemaha R at Auburn, Nebr 06811500)	S136 23131	2	2	0	2
LNR-18	Whiskey Run at CR, Nemaha Co (sec 12/13, T4N, R15E)	C064 13060	1	0	0	2
LNR-19	Little Nemaha R at N67 near Nemaha	S067 01234	1	0	0	2
	Big Nemaha River Basin					
BNR-1	N Fk Big Nemaha R at SE 148th St, Lancaster Co	C055 04305	1	1	1	2
BNR-2	M Br Big Nemaha R at S34B	SS34B 00455	1	0	0	2
BNR-3	M Br Big Nemaha R at N41	S041 08540	1	0	0	2
BNR-4	Yankee Cr at CR, Johnson Co (near center of S 1/2, sec 8, T4N, R9E)	C049 00305P	2	2	0	2
BNR-5	Yankee Cr at US136	S136 20392	1	0	0	2
BNR-6	N Fk Big Nemaha at US136	S136 20939	1	1	0	2
BNR-7	Long Branch Cr at N62	S062 00820	2	2	1	2
BNR-8	Kirkham Cr at CR, Richardson Co (near center sec 32, T3N, R13E)	C074 00305P	2	2	0	2
BNR-9	N Fk Big Nemaha R at N105 (N Fk Big Nemaha R at Humboldt, Nebr 06814500)	S105 00703	2	2	1	2
BNR-10	Turkey Cr at CR, Pawnee Co (sec 3/4, T3N, R9E)	C067 00735	1	0	0	2
BNR-11	Turkey Cr at N8	S008 11290	1	1	0	2

Table 1. Study sites and types of soil data collected for analysis of channel-bank stability in eastern Nebraska, 1995 to 1999—Continued

Site ID	Station name[a]	NDOR bridge ID	Bank material			
			No. of samples analyzed for soil unit weight	No. of samples analyzed for particle size	No. of samples analyzed for Atterburg limits	Soil group[b]
	Big Nemaha River Basin—Continued					
BNR-12	Johnson Ck at CR, Pawnee Co (sec 25/30, T1N, R10/11E)	C067 02505	1	1	0	2
BNR-13	S Fk Big Nemaha at N8	S008 12578	2	2	0	2
BNR-14	Big Nemaha R at US73 (Big Nemaha R at Falls City, Nebr 06815000)	S073 00248	2	2	1	2
BNR-15	Muddy Cr at N105	S105 02688	1	0	0	2
BNR-16	Muddy Cr at US75	S075 01884	2	2	0	2
BNR-17	Muddy Cr at US73	S073 01612	3	3	1	2
	Big Blue River Basin					
BBR-1	Big Blue R at CR "D", Butler Co (Big Blue R at Surprise, Nebr 06879900)	C012 00705	1	1	1	1
BBR-2	N Br Big Blue R at S12E	SS12E 00100	1	0	0	1
BBR-3	Kezan Cr at N15	S015 08602	1	1	0	1
BBR-4	N Br Big Blue R at CR "J", Butler Co	C012 01915	1	0	0	3
BBR-5	Big Blue R at CR 2250, Saline Co (Big Blue R near Crete, Nebr 06881000)	C076 14315P	1	1	0	3
BBR-6	Turkey Cr at N41	S041 05764	1	0	0	3
BBR-7	Turkey Cr at N103	S103 02465	1	1	0	3
BBR-8	Indian Cr trib at US77	S077 03378	1	1	0	3
BBR-9	Indian Cr at US77 (Indian Ck at Beatrice 06881450)	S077 02364	1	0	0	3
BBR-10	Big Blue R at US77	S077 02160	2	2	0	3
BBR-11	Big Indian Cr at CR, Gage Co (sec 33/4, T2/11N, R5E)	C034 06210	1	1	0	3
BBR-12	Big Indian Cr at US77	S077 00775	1	0	0	3
BBR-13	Big Blue R at N8 (Big Blue R at Barneston, Nebr 06882000)	S008 08619	1	1	0	3

[a] Naming convention for stations is as follows: Stream name; U.S. route, state route, county road, or municipal street. Where a county road or municipal street is used, the county or municipality name follows the site name. Where the county road or municipal street name is not known, the section, township, and range location are given. Where sites are located at a USGS gaging station, the station name and number are listed in parenthesis.

[b] Dugan (1984).

Table 2. Channel-geometry data collected at study sites in eastern Nebraska, 1995 to 1999

[ID, identification; m, meter; °, degree; --, insufficient data]

Site ID	Soil group[a]	Average bank height (m)	Average unweighted bank angle (°)	Average vertically weighted bank angle (°)	Average horizontally weighted bank angle (°)	Average linearly weighted bank angle (°)	Average bank to bank width (m)	Average toe to toe width (m)
Missouri River Tributary Basins								
MRT-1	2	3.09	26.65	44.57	22.80	28.28	25.29	7.28
MRT-2	2	3.36	15.67	25.20	14.42	15.90	56.71	32.95
MRT-3	2	2.64	21.01	28.37	19.55	21.14	20.81	6.75
MRT-4	2	7.82	40.10	46.28	34.47	40.14	25.57	5.30
MRT-5	2	4.99	39.40	47.13	36.24	40.56	29.65	17.32
MRT-6	2	6.13	28.82	35.06	26.56	28.86	35.94	12.87
MRT-7	2	3.62	40.13	42.36	38.47	40.14	13.80	5.43
MRT-8	2	6.40	41.80	45.57	38.58	41.87	22.17	7.36
MRT-9	2	4.74	25.22	34.32	22.85	25.24	25.54	4.07
MRT-10	2	9.02	42.55	46.03	37.67	40.90	33.45	12.67
MRT-11	2	6.87	23.04	28.98	21.06	23.28	41.54	9.29
MRT-12b	2	5.82	34.38	40.10	30.98	34.56	23.74	5.31
MRT-13	2	3.05	25.49	30.22	24.27	25.53	19.55	5.33
MRT-14	2	--	--	--	--	--	--	--
MRT-15	2	5.06	26.95	35.53	23.70	26.58	28.16	7.57
MRT-16	2	6.52	25.05	31.58	23.20	25.02	43.37	10.31
MRT-17	2	5.41	44.96	52.51	35.94	44.83	18.72	7.39
Papillion Creek Basin								
PC-1	2	3.91	31.41	36.05	29.40	31.48	16.41	2.66
PC-2	2	5.08	36.86	41.70	34.16	36.94	21.66	5.39
PC-3	2	3.46	26.15	31.30	24.81	26.15	20.19	4.35
PC-4	2	7.98	41.56	45.66	38.69	41.61	23.16	3.95
PC-5	2	8.44	23.18	27.33	22.16	23.25	51.31	9.89
PC-6	2	--	--	--	--	--	--	--
PC-7	2	7.42	22.66	33.99	21.23	24.24	40.89	4.59
PC-8	2	7.49	36.49	43.86	31.38	36.64	25.82	5.00
PC-9	2	3.74	33.18	38.13	30.30	33.27	16.64	3.79
PC-10	2	3.81	30.81	33.84	29.24	30.90	24.65	10.95
PC-11	2	6.13	36.52	38.12	35.40	36.55	22.07	5.00
PC-12	2	5.15	27.78	37.63	25.59	29.41	39.10	18.51
Platte River Tributary Basins								
PRT-1	2	4.86	32.44	37.73	30.12	32.57	23.85	7.63
PRT-2	2	5.42	31.23	36.62	29.10	31.33	33.77	14.54
PRT-3	2	3.05	27.27	39.52	24.11	27.83	14.61	1.61
PRT-4	2	3.06	37.97	44.67	33.48	38.20	10.98	3.02
PRT-5	3	9.10	44.99	53.37	34.76	45.15	30.07	11.45
PRT-6	3	5.88	31.95	37.61	28.90	32.12	26.52	6.99
PRT-7	1	6.08	44.35	53.93	34.36	44.84	16.59	3.92
PRT-8	1	3.99	28.13	39.01	24.35	28.46	23.14	7.54
PRT-9	2	6.06	44.01	51.34	38.00	43.93	15.01	2.34

Table 2. Channel-geometry data collected at study sites in eastern Nebraska, 1995 to 1999—Continued

[ID, identification; m, meter; °, degree; --, insufficient data]

Site ID	Soil group[a]	Average bank height (m)	Average unweighted bank angle (°)	Average vertically weighted bank angle (°)	Average horizontally weighted bank angle (°)	Average linearly weighted bank angle (°)	Average bank to bank width (m)	Average toe to toe width (m)
Platte River Tributary Basins—Continued								
PRT-10	2	6.24	30.00	33.99	28.81	30.02	30.90	5.68
PRT-11	2	6.01	39.03	42.26	38.54	39.03	25.65	4.74
PRT-12	2	6.64	38.85	43.75	35.78	38.93	24.27	7.02
PRT-13	2	5.15	42.31	47.63	37.50	42.39	32.74	20.99
Elkhorn River Basin								
ER-1	4	--	--	--	--	--	--	--
ER-2	3	--	--	--	--	--	--	--
ER-3	3	4.64	36.79	40.30	33.68	36.82	36.07	23.42
ER-4	2	2.60	34.63	41.60	31.17	34.75	10.44	2.41
ER-5	2	5.77	34.35	44.71	27.60	34.65	26.02	6.19
ER-6	4	3.25	41.78	41.78	41.78	41.78	99.53	93.40
ER-7	2	4.54	32.73	34.46	30.17	32.01	17.88	3.78
ER-8	4	4.88	30.46	39.40	26.84	30.71	21.60	4.63
ER-9	2	5.08	29.43	36.61	26.49	29.66	31.29	12.75
ER-10	2	2.47	34.05	40.60	31.83	34.14	11.51	3.55
ER-11	2	0.64	21.03	24.19	20.74	21.07	6.05	2.29
ER-12	2	6.91	38.07	42.13	35.23	38.13	30.46	10.84
ER-13	2	5.99	35.04	38.92	34.58	36.06	38.79	21.01
ER-14	2	5.05	32.38	36.59	30.34	32.45	42.83	26.86
ER-15	2	4.92	32.35	40.28	28.54	32.52	41.22	24.35
ER-16	2	4.34	30.55	43.23	24.28	31.12	18.85	3.09
ER-17	2	4.56	31.98	36.94	30.31	32.04	18.19	2.71
ER-18	2	3.90	31.91	39.95	27.84	32.27	18.48	5.68
ER-19	2	4.74	33.77	38.22	31.05	33.94	33.60	18.68
ER-20	2	3.65	35.36	40.18	31.81	36.03	35.68	24.71
ER-21	2	2.94	39.84	42.27	38.17	36.13	24.77	17.28
ER-22	2	1.84	33.28	36.68	31.59	33.28	11.23	5.59
ER-23	2	3.56	31.57	36.80	29.68	31.67	15.70	3.96
ER-24	2	4.30	36.85	39.33	35.04	36.91	21.65	9.82
ER-25	4	4.17	31.03	35.01	29.67	26.96	84.49	69.79
Salt Creek Basin								
SC-1	2	2.96	37.92	42.72	33.72	38.04	13.92	5.53
SC-2	2	3.62	46.03	50.05	40.54	46.13	11.24	4.15
SC-3	2	5.04	23.28	37.46	20.99	24.78	30.60	6.44
SC-4	2	2.71	29.67	32.44	28.62	29.73	17.25	3.84
SC-5	2	3.67	40.54	46.51	34.37	40.79	13.62	3.86
SC-6	2	8.34	29.20	33.84	27.88	29.24	38.35	6.81
SC-7	2	4.97	33.66	43.15	28.21	33.94	20.13	4.27
SC-8	2	6.04	33.26	40.44	31.26	35.22	28.11	9.64
SC-9	2	3.21	27.44	34.92	25.60	27.63	16.29	2.67

Table 2. Channel-geometry data collected at study sites in eastern Nebraska, 1995 to 1999—Continued

[ID, identification; m, meter; °, degree; --, insufficient data]

Site ID	Soil group[a]	Average bank height (m)	Average unweighted bank angle (°)	Average vertically weighted bank angle (°)	Average horizontally weighted bank angle (°)	Average linearly weighted bank angle (°)	Average bank to bank width (m)	Average toe to toe width (m)
Salt Creek Basin—Continued								
SC-10	2	4.75	24.19	33.93	21.51	24.43	27.21	4.54
SC-11	2	7.92	24.05	33.44	21.79	24.28	48.09	11.43
SC-12	2	4.74	37.21	47.12	30.31	37.84	17.62	4.57
SC-13	2	9.59	24.45	31.82	22.10	24.66	90.84	39.98
SC-14	1	3.91	42.52	42.80	42.25	42.52	12.48	3.98
SC-15	1	2.84	27.90	39.59	24.12	28.36	12.05	1.08
SC-16	2	1.98	29.61	48.30	22.45	31.16	10.05	2.13
SC-17	1	1.96	38.62	48.33	31.57	38.88	6.77	1.84
SC-18	1	1.15	47.53	48.05	41.12	46.29	6.62	4.40
SC-19	1	2.65	31.46	37.51	28.06	31.91	10.43	1.37
SC-20	2	--	--	--	--	--	--	--
SC-21	2	6.73	39.69	44.48	35.99	39.80	25.88	9.66
SC-22	2	9.68	35.31	40.26	32.18	34.36	60.96	33.31
SC-23	2	4.94	29.29	39.03	26.16	29.87	24.02	6.00
SC-24	2	4.02	25.25	35.97	21.32	25.67	20.42	3.01
SC-25	2	5.44	38.21	42.50	35.24	37.98	25.37	10.81
SC-26	2	7.52	37.64	43.00	33.17	37.96	66.55	46.25
SC-27	2	6.14	28.21	40.53	24.26	29.40	29.57	6.21
SC-28	2	4.97	27.21	36.12	20.29	24.35	25.79	3.55
SC-29	1	4.33	36.43	42.68	32.16	36.48	14.75	2.47
SC-30	2	5.66	44.61	47.93	40.57	44.76	17.59	6.13
SC-31	3	1.54	27.83	30.82	25.32	27.79	7.23	2.00
SC-32	3	7.84	39.94	45.70	35.08	40.08	24.31	4.51
SC-33	2	5.13	23.27	35.84	20.46	24.11	30.60	6.20
SC-34	2	2.42	23.28	31.59	22.90	24.26	14.23	1.40
Little Nemaha River Basin								
LNR-1	2	4.87	29.61	39.81	25.16	30.03	25.61	8.01
LNR-2	2	4.39	32.38	36.29	30.49	30.99	17.88	3.38
LNR-3	2	4.68	34.10	37.82	32.36	34.15	20.13	5.72
LNR-4	2	5.24	31.13	37.30	28.81	31.25	25.43	7.20
LNR-5	2	10.18	36.26	40.34	33.78	36.31	46.73	18.37
LNR-6	2	8.87	44.70	53.08	34.66	44.87	29.40	9.84
LNR-7	2	4.16	37.20	45.14	31.95	37.31	19.22	6.63
LNR-8	2	9.73	44.58	52.47	35.89	44.88	38.09	16.10
LNR-9	1	4.24	35.64	38.94	34.29	35.64	15.97	3.92
LNR-10	1	2.90	21.22	31.12	18.82	21.58	17.44	1.87
LNR-11	2	7.37	39.99	48.22	33.08	40.05	25.78	7.19
LNR-12	2	4.64	31.57	41.65	27.34	30.24	22.62	5.82
LNR-13	2	5.58	24.20	36.37	20.98	24.57	32.61	6.79
LNR-14	2	8.16	20.73	29.85	20.30	21.57	91.85	44.43
LNR-15	2	4.78	28.01	32.98	26.34	28.11	22.28	3.90

Table 2. Channel-geometry data collected at study sites in eastern Nebraska, 1995 to 1999—Continued

[ID, identification; m, meter; °, degree; --, insufficient data]

Site ID	Soil group[a]	Average bank height (m)	Average unweighted bank angle (°)	Average vertically weighted bank angle (°)	Average horizontally weighted bank angle (°)	Average linearly weighted bank angle (°)	Average bank to bank width (m)	Average toe to toe width (m)
Little Nemaha River Basin—Continued								
LNR-16	2	5.49	35.60	42.83	30.63	35.60	24.99	8.40
LNR-17	2	6.33	32.17	34.47	31.08	32.20	56.20	35.61
LNR-18	2	2.26	31.93	37.12	29.28	31.79	16.50	9.01
LNR-19	2	3.12	16.85	24.54	15.93	16.92	57.16	34.84
Big Nemaha River Basin								
BNR-1	2	3.79	46.72	50.16	42.84	47.00	11.40	4.10
BNR-2	2	5.08	34.87	38.34	32.99	34.92	19.56	4.55
BNR-3	2	5.13	30.46	37.53	27.37	30.57	27.49	9.56
BNR-4	2	4.58	44.08	48.21	36.20	42.86	16.54	6.53
BNR-5	2	5.60	18.58	23.66	17.55	18.73	39.51	7.48
BNR-6	2	6.76	36.20	43.06	32.42	36.24	52.91	23.24
BNR-7	2	5.12	35.45	43.09	30.78	35.83	22.05	6.69
BNR-8	2	4.52	36.62	41.97	31.03	36.54	20.15	4.36
BNR-9	2	10.45	25.52	31.03	23.97	25.39	79.47	32.08
BNR-10	2	2.49	37.39	41.82	34.54	37.52	9.06	2.54
BNR-11	2	4.58	39.29	46.89	33.41	39.37	20.02	8.24
BNR-12	2	2.38	34.60	39.13	32.09	34.65	17.04	9.43
BNR-13	2	8.27	35.90	44.88	29.18	35.73	65.46	39.13
BNR-14	2	7.44	24.83	28.05	23.96	24.89	80.35	48.12
BNR-15	2	3.95	24.41	27.59	23.54	24.50	20.61	3.19
BNR-16	2	9.41	30.58	37.11	28.41	30.65	48.83	11.27
BNR-17	2	7.54	27.21	34.01	24.82	27.47	50.30	19.79
Big Blue River Basin								
BBR-1	1	3.36	29.06	36.45	26.64	29.17	19.66	6.52
BBR-2	1	0.94	40.77	47.03	36.41	40.86	5.83	3.59
BBR-3	1	1.74	45.14	50.16	42.46	45.25	6.46	2.12
BBR-4	3	3.02	29.57	36.39	27.32	29.60	15.92	5.14
BBR-5	3	4.14	36.93	39.09	35.42	36.99	37.63	26.25
BBR-6	3	2.25	25.90	28.92	25.13	25.89	24.53	12.88
BBR-7	3	2.79	28.99	36.93	24.91	28.90	31.78	20.41
BBR-8	3	4.52	24.81	35.23	21.41	25.20	25.44	5.56
BBR-9	3	4.60	34.53	43.78	27.36	34.85	22.19	6.36
BBR-10	3	4.45	29.56	34.98	28.09	30.27	63.41	44.75
BBR-11	3	3.85	30.97	39.11	27.87	31.27	18.23	5.11
BBR-12	3	3.55	51.08	53.27	47.28	51.11	33.43	27.07
BBR-13	3	5.80	33.51	36.21	33.02	33.54	75.71	56.21

[a] Dugan (1984).

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999

[ID, identification; m, meter; *c*, cohesion; kPa, kilopascals; ϕ, friction angel; °, degree; BST status, borehole shear test status: 1, used (good); 2, used (fair); 3, not used (questionable); γ, soil unit weight; kN/m^3, kilonewtons per cubic meter; amb, ambient conditions; sat, saturated conditions; %, percent; NASIS, National Soil Information System: S, sand; LS, loamy sand; SL, sandy loam; L, loam; SIL, silt loam; CL, clay loam; SICL, silty clay loam; SIC, silty clay; GR, gravelly; GRV, very gravelly; GRX, extremely gravelly; --, no data]

Site ID	Sample depth (m)	*c* (kPa)	ϕ (°)	BST status	Soil unit weight (kN/m^3)		Moisture content (%)	Degree of saturation (%)	Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
					Ambient (γ_{amb})	Saturated (γ_{sat})			Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
Missouri River Tributary Basins															
MRT-1	2.5	13.7	28.9	1	18.1	18.7	28.7	88.2	--	9.4	54.1	37.6	SICL	--	--
MRT-2	1.8	3.2	27.9	2	17.5	17.6	42.1	99	--	17.1	71.1	11.9	SIL	35	10
MRT-3	2	2.5	32.2	1	17.9	18.6	28	84.7	--	--	--	--	--	--	--
MRT-4	1.1	4.8	30.7	1	18	19.2	20.3	71	--	17.6	63.8	18.7	SIL	--	--
MRT-5	1.4	27.3	21.3	3	17.3	18.9	20	64.4	--	15.1	67.7	17.3	SIL	--	--
MRT-6	2.3	8.1	29.7	2	18.5	18.9	28.5	91.2	--	--	--	--	--	--	--
MRT-7	1.7	3.3	25.2	1	17.3	18.3	28.7	79.9	--	--	--	--	--	--	--
MRT-8	1.4	8.7	26.6	2	17.2	17.9	33.9	86.3	--	5	68.9	26.1	SIL	--	--
MRT-9	0.7	23.6	15.7	3	16.6	18.2	25	67.7	--	17.8	59.9	22.4	SIL	45	17
	2.1	7.7	26.6	1	16.1	17.2	36.7	79.4	--	7.1	68.6	24.3	SIL	--	--
MRT-10	1.9	6.6	39	1	17.5	19.2	17	59.9	--	14.2	70.1	17.3	SIL	--	--
	2.3	16.8	29.8	1	15.6	18	21	54.1	--	--	--	--	--	--	--
	6.1	11.3	34.6	1	16.1	18.1	22.6	60	--	21.9	59	19.1	SIL	35	10
MRT-11	1.4	11.2	29.9	1	17.5	18.6	25.4	76.2	--	6.7	71	22.8	SIL	--	--
MRT-12b	1.1	10.7	27.9	1	17.7	18.7	25.1	77.4	--	4.5	71.8	23.6	SIL	--	--
MRT-13	1.6	7.7	24.1	1	16.9	17.9	32.3	81.2	--	8.8	64.8	26.4	SIL	--	--
MRT-14	1.5	3.5	23	2	16.7	17.8	31	77.6	--	--	--	--	--	--	--
MRT-15	1.1	13.5	27.2	1	16.9	18.3	25.6	71.3	--	--	--	--	--	--	--
MRT-16	2.3	8.6	31.6	3	17.9	18	37.3	98.1	--	20.2	60.9	18.8	SIL	--	--
	5.7	9.1	24.4	3	18.7	18.9	29.9	96	--	28.2	55	16.8	SIL	--	--
MRT-17	3.6	16	27.6	2	18.6	19	28.1	92.3	--	29.6	56.5	13.9	SIL	32	9

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

					Soil unit weight (kN/m^3)				Particle-size distribution (%)					Atterburg limits (%)	
Site ID	Sample depth (m)	*c* (kPa)	ϕ (°)	BST status	Ambient (γ_{amb})	Saturated (γ_{sat})	Moisture content (%)	Degree of saturation (%)	Gravel	Sand	Silt	Clay	NASIS textural Class and modifier	Liquid limit	Plasticity index
							Papillion Creek Basin								
PC-1	1.1	13	29.2	3	17.4	18.1	31.5	84.9	--	8.9	66.2	24.9	SIL	34	24
	1.7	12.4	29.4	1	17.3	18.5	24.5	72.8	--	13.5	67.6	19	SIL	--	--
PC-2	0.8	23	17.7	2	13.7	16.2	34.7	58.7	--	9.9	64.9	25.2	SIL	--	--
	0.9	44.2	13.8	3	18.8	19.3	24.8	87.8	--	11.2	67.7	21.1	SIL	--	--
	2.1	4	38.2	1	16.2	18.6	15.9	47.7	--	4.3	67.2	28.5	--	48	26
PC-3	1.4	12.3	23.4	2	17.2	18.3	27.9	77.3	--	--	--	--	--	--	--
PC-4	2.3	11.5	36.4	2	14.2	17.5	15.8	36.8	--	--	--	--	--	--	--
PC-5	1.6	14.5	25	1	17.7	18.6	26.7	80.6	--	4.3	63.2	34.1	SICL	--	--
PC-6	1.3	4.7	27.6	1	16.9	18.1	28.5	76.4	--	3.1	75.1	21.8	SIL	--	--
PC-7	1.6	11.4	20.6	1	17.2	17.9	34.3	86.5	--	--	--	--	--	--	--
PC-8	2.5	7.6	26	1	17.9	18.3	32.4	91.7	--	--	--	--	--	--	--
PC-9	1	24	21.8	1	15.8	17.4	30.6	69.3	--	2.9	77.6	19.5	SIL	--	--
PC-10	2.2	9.2	26	1	17.2	18.2	29.3	80	--	2.2	76	21.9	SIL	--	--
PC-11	1.7	8.9	23.8	1	18.5	19.3	23	82.1	--	--	--	--	--	--	--
PC-12	2.6	4.5	28.8	1	15.8	17.1	37.4	77.6	--	2.8	64.5	32.8	SICL	--	--
							Platte River Tributary Basins								
PRT-1	1.2	14.9	22.6	3	18.3	19.1	23.8	81.6	--	15.7	65.7	18.6	SIL	--	--
PRT-2	1.7	12.3	30.5	1	14	17.6	12.6	30.1	--	35.5	46	18.6	L	--	--
PRT-3	1.1	3.6	30.1	3	17.8	18.5	28.5	84.2	--	11.5	65.8	22.8	SIL	--	--
PRT-4	0.7	4.2	27.5	1	17.9	18.6	28.4	84.8	--	14.3	59.1	26.6	SIL	--	--
PRT-5	2.6	7.1	30.4	2	15.2	18.3	13.6	37.8	--	14.4	67	18.6	SIL	--	--
PRT-6	1.5	15.8	29.3	1	17.2	18.5	25.3	73.6	--	15.5	61.2	23.3	SIL	--	--
PRT-7	1.4	12.8	29.5	2	15.4	17.8	21.9	53.9	--	12.7	67.4	22	SIL	--	--
PRT-8	1.7	16.9	25.4	1	16.4	18	26.6	68.9	--	--	--	--	--	--	--

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

Site ID	Sample depth (m)	c (kPa)	ϕ (°)	BST status	Soil unit weight (kN/m^3)		Moisture content (%)	Degree of saturation (%)	Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
					Ambient (γ_{amb})	Saturated (γ_{sat})			Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
Platte River Tributary Basins—Continued															
PRT-9	1.5	4.5	33	2	15.9	17.7	26.9	65.1	--	--	--	--	--	--	--
PRT-10	1.5	6.5	29.1	1	17	18.3	25.7	72.8	--	4.2	78.5	17.3	SIL	32	10
PRT-11	2.1	14	21.5	1	17.2	17.8	34.7	86.8	--	--	--	--	--	--	--
PRT-12	1.7	4.7	24.6	1	17.6	18.3	30.4	85	--	6.1	75.6	19.5	SIL	--	--
PRT-13	1.7	6	25	1	15.7	17.2	34.4	73.3	--	--	--	--	--	--	--
Elkhorn River Basin															
ER-2	1.3	4.1	22.9	1	17.4	18.2	30.4	83.9	--	16.8	56.2	28.2	SICL	45	17
ER-3	3	4.2	33.6	1	17.1	19.5	11	41.4	--	--	--	--	--	--	--
ER-4	1.2	17	25	1	16.3	17.8	29.2	71.6	--	--	--	--	--	--	--
ER-5	1.9	19.4	28.4	1	13.8	17.2	18	38.2	--	9.3	59.6	31.2	SICL	--	--
ER-6	0.3	0	32.8	2	20.2	22.4	0.9	7.4	--	81.2	12.1	7	LS	--	--
ER-7	1.1	9.1	33.1	1	15.1	18	15.9	41.6	--	8	68.6	28.1	SICL	--	--
	1.5	--	--	--	15.9	17.5	30.7	70.4	--	--	--	--	--	--	--
ER-8	2.2	17	19.3	3	18.6	19	27.9	92.2	--	--	--	--	--	--	--
ER-9	1.3	9.5	31.7	1	14.5	17.1	24.9	52.4	--	8.8	62.7	28.6	SICL	43	23
ER-10	1.3	12.5	26.6	1	17.2	18.2	28.7	79	--	16.1	64.9	20.9	SIL	--	--
ER-11	1.2	14.6	28.1	1	17.7	18.8	24.7	77.4	--	9.6	58.4	32.9	SICL	51	30
ER-12	1.5	10.3	26.5	2	18.7	19.1	26.6	90.9	--	12.6	66.2	21.2	SIL	--	--
ER-13	1.6	23.4	29.2	2	15	17.8	17.6	44	--	--	--	--	--	--	--
ER-14	1.4	10.8	29.2	1	16.5	19.3	9.9	35.1	--	55.3	31.4	13.3	SL	--	--
	3.8	17.5	24.6	1	18.5	19.2	23.8	83.7	--	30.2	49.8	19.9	L	--	--
ER-15	1.1	16.7	10.7	1	17	18.6	22.3	66.8	--	12.5	59.5	28.9	SICL	--	--
	3	--	--	--	18.3	18.9	26.8	86.2	--	26.1	48.1	27.2	CL	--	--
ER-16	1.2	4.7	35	2	14.7	17.1	26.4	55.6	--	7.6	63.5	28.9	SICL	--	--
ER-17	1.4	11	28.1	2	15.2	18.1	14.6	39.5	--	9.3	63.4	27.3	SICL	38	17

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

Site ID	Sample depth (m)	c (kPa)	ϕ (°)	BST status	Soil unit weight (kN/m^3)		Moisture content (%)	Degree of saturation (%)	Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
					Ambient (γ_{amb})	Saturated (γ_{sat})			Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
								Elkhorn River Basin—Continued							
ER-18	1.7	3.2	30.9	1	16.3	17.3	37	81.6	--	--	--	--	--	--	--
ER-19	1.7	5	30.3	2	14.5	17.6	17.1	40.7	--	--	--	--	--	--	--
ER-20	0.5	14.6	21.9	1	17.4	18.6	24.1	73.2	--	10.4	65.3	24.3	SIL	--	--
	2	20	22	2	17.5	18.7	24.6	75.4	--	14.2	56.6	29.3	SICL	--	--
ER-22	1	17.3	20.1	2	17.5	17.9	35.7	91.6	--	3.2	45.8	53.9	SIC	--	--
ER-23	1.1	5.7	31	1	18.4	19.3	22.7	80.1	--	--	--	--	--	--	--
ER-24	1.5	11	27.2	1	16.9	18.3	25.8	71.8	--	5.3	70.9	23.9	SIL	--	--
ER-25	1	6.7	30.4	2	16.3	18.8	13.7	43.5	--	45.1	43.9	26.3	L	--	--
	4.4	--	--	--	--	--	--	--	--	84.2	11.6	5.8	LS	--	--
								Salt Creek Basin							
SC-1	1.2	7.8	25.8	1	16.8	18.1	27.4	73.6	--	12.8	63.4	23.8	SIL	--	--
SC-2	1.3	2.5	37.1	1	14.6	17.5	20.5	47	--	--	--	--	--	--	--
SC-3	2.2	8.5	32.8	2	15.7	17.5	28.1	65.3	--	20.6	57.4	22	SIL	35	15
	4.5	9.3	16.4	3	17.5	17.8	37	93	--	23.8	57.8	18.4	SIL	--	--
SC-4	1.2	2.7	34.3	2	15.6	18.2	16.7	46.1	--	7.2	70.5	22.3	SIL	--	--
SC-5	1.4	9.8	28.8	2	15.8	17.7	25.9	63	--	--	--	--	--	--	--
SC-6	1.7	5	32.7	1	14.6	18	12.6	32.5	--	4	72.1	23.9	SIL	--	--
SC-7	1.6	14	26.6	1	16.1	17.6	30.9	72.4	--	--	--	--	--	--	--
SC-8	1.5	12	31.4	1	16.6	18.3	23.6	65.4	--	--	--	--	--	--	--
SC-9	2.2	13	26.6	1	18.2	19	24.3	80.8	--	33.7	59.9	21.9	SIL	--	--
SC-10	1.1	11.7	23	1	17.7	18.2	31.8	88	--	--	--	--	--	--	--
SC-11	1.5	14.6	26	1	17.7	18.5	28	82.4	--	5.9	52.3	41.8	SIC	--	--
SC-12	2.5	8.6	27	1	17.4	18.3	29.2	81.8	--	--	--	--	--	--	--
SC-13	6.4	8.7	35.6	1	18	19	23.5	78	--	18.8	61.8	19.4	SIL	--	--
SC-14	1.4	15.1	36.9	2	16.3	18.4	20.3	57.7	--	19.3	51.8	28.9	SICL	40	17

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

Site ID	Sample depth (m)	*c* (kPa)	ϕ (°)	BST status	Soil unit weight (kN/m^3)		Moisture content (%)	Degree of saturation (%)	Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
					Ambient (γ_{amb})	Saturated (γ_{sat})			Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
							Salt Creek Basin—Continued								
SC-15	1	12.8	14	3	18	18.6	28.4	85.7	--	--	--	--	--	--	--
SC-16	0.5	14.1	21.5	1	13.5	16.3	30.3	52.6	--	18.2	65.3	16.5	SIL	--	--
SC-17	1	13.8	26.6	2	--	--	--	--	--	--	--	--	--	--	--
	1.4	16.3	13	3	17.2	18.1	31.5	83.4	--	22.6	56.3	21	SIL	34	14
	1.5	7.7	17.7	3	17.1	18	31.5	82	--	--	--	--	--	--	--
SC-18	0.8	3.5	24.6	2	17.6	18.1	33.3	89.2	--	41.1	42.5	16.4	L	--	--
SC-19	1	36	15.3	3	16.7	17.8	31.8	78.8	--	21.8	57.8	20.4	SIL	36	13
SC-20	1.5	8.5	14	3	18.4	19.4	20.8	76.5	--	42.2	43.5	14.3	L	27	8
	1.9	22.2	26.7	2	--	--	--	--	--	--	--	--	--	--	--
SC-21	2	--	--	--	18.6	19.6	19.3	74.8	--	--	--	--	--	--	--
	2	44.7	15.8	3	18.6	19.9	16.1	66.5	--	25	56.2	18.9	SIL	--	--
	3.3	--	--	--	17.2	18.5	24.6	72.4	--	--	--	--	--	--	--
	4	0	15.3	3	17.6	20.1	7.7	33.7	--	--	--	--	--	--	--
SC-22	2.4	8.1	35.9	1	18.4	19.5	18.8	71	--	22.7	50.8	26.6	SIL	38	22
SC-23	2.2	16	35.2	1	17.3	18.6	24	71.7	--	18.2	45.2	36.7	SICL	--	--
	4.4	7.1	28.4	1	19.2	19.3	27.4	97.5	--	15.7	53.3	30.9	SICL	45	24
SC-24	1.1	11.2	20.3	2	17.8	18.6	26.9	81.3	--	--	--	--	--	--	--
SC-25	1.3	2.2	31.8	1	18.7	19.4	22.9	83.2	--	6.8	69	24.1	SIL	--	--
	2.2	7	21.8	2	18.7	19.1	26.8	90.8	--	6.6	63.3	31.1	SICL	--	--
SC-26	2	10	42.1	1	15.9	18.5	14.5	43	--	18.4	56	25.6	SIL	38	19
	2.4	7	32.1	1	15.3	18.1	16.3	43.2	--	--	--	--	--	--	--
SC-27	1.1	15.7	21.8	2	16.5	18.4	20.6	59.5	--	--	--	--	--	--	--
SC-28	1.7	12.6	23.1	2	16.2	17.5	33	75.8	--	32.2	53.8	22.4	SIL	--	--
SC-29	1.7	20.4	19.3	1	15.2	17.2	30.3	64.6	--	5.9	69.6	24.5	SIL	42	22
SC-30	1.9	9.4	33.8	1	12.6	16.7	15.9	30	--	--	--	--	--	--	--
SC-31	0.6	3.1	27.9	1	16.7	17.6	34.9	82.9	--	--	--	--	--	--	--

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

Site ID	Sample depth (m)	*c* (kPa)	ϕ (°)	BST status	Soil unit weight (kN/m^3)		Moisture content (%)	Degree of saturation (%)	Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
					Ambient (γ_{amb})	Saturated (γ_{sat})			Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
Salt Creek Basin—Continued															
SC-32	2.8	6.5	30.6	1	18.3	19.5	18.9	71	--	13.2	60.5	27.1	SICL	--	--
SC-33	2.5	2.3	36.4	2	17.2	18.3	27.8	77.2	--	--	--	--	--	39	18
	3.9	0	0	3	18.3	18.6	31.1	93.6	--	80.7	7	12.2	SL	--	--
SC-34	1.8	7.4	33.1	1	17.7	18.4	28.7	83.2	--	--	--	--	--	--	--
Little Nemaha River Basin															
LNR-1	1.8	16.6	21	1	18.6	19.3	23.3	83.6	--	--	--	--	--	--	--
LNR-2	1.6	19.4	25.8	1	16.2	18.2	20.7	57.2	--	--	--	--	--	--	--
LNR-3	1.5	7.9	31.5	1	18	18.7	27.3	84.6	--	17.1	60	22.9	SIL	--	--
LNR-4	1.3	15.1	34	2	--	18.5	--	--	--	--	--	--	--	--	--
LNR-5	--	12.8	23	1	--	--	--	--	--	--	--	--	--	--	--
LNR-6	1.8	12.7	29.2	1	--	17.2	--	--	--	5.7	72.6	21.6	SIL	--	--
LNR-7	0.9	8.8	22.5	2	17.4	18.5	25.8	75.9	--	21.2	57.3	21.6	SIL	--	--
LNR-8	1.5	6.5	33.5	1	15.8	18.8	10.4	33.3	--	--	--	--	--	--	--
LNR-9	1.4	13.3	26.5	2	18.5	19.3	22.3	80.2	--	--	--	--	--	--	--
LNR-10	0.9	36.5	15.3	2	16.4	18	25.5	67.2	--	--	--	--	--	--	--
LNR-11	3.2	19.6	34.4	3	19.2	20.5	13.3	63.4	--	36.2	42.2	21.6	L	--	--
LNR-12	1.3	7.7	26.2	2	18	19.1	21.4	73.3	--	--	--	--	--	--	--
LNR-13	1.5	12.8	24.7	1	15	17.4	24.3	55	--	--	--	--	--	--	--
LNR-14	1.7	--	--	--	14.7	18.2	10.9	29.7	--	--	--	--	--	--	--
	2.4	18.9	33.7	3	16.5	19	12.9	43.1	--	--	--	--	--	--	--
LNR-15	2	12.9	28.8	1	18.8	19.5	22.2	83	--	--	--	--	--	--	--
LNR-16	1	17.2	34.2	2	16	18.3	18.9	52.6	--	3.2	70.7	26.1	SIL	--	--
	4.7	3.1	38.7	2	17.7	18.4	29.5	84.5	--	22.8	58.6	18.7	SIL	32	13
LNR-17	1.6	--	--	--	18.1	19.6	16.8	64.3	--	15.8	55.1	29.1	SICL	--	--
	5.5	15.5	27.9	2	18.1	18.4	33	94.5	--	20.5	61.2	18.2	SIL	--	--

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

Site ID	Sample depth (m)	c (kPa)	ϕ (°)	BST status	Soil unit weight (kN/m^3)		Moisture content (%)	Degree of saturation (%)	Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
					Ambient (γ_{amb})	Saturated (γ_{sat})			Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
							Little Nemaha River Basin—Continued								
LNR-18	1.3	12.2	23	1	17.6	18.2	32.3	88	--	--	--	--	--	--	--
LNR-19	1.1	23.8	19.6	1	18.3	19	25.2	84.1	--	--	--	--	--	--	--
							Big Nemaha River Basin								
BNR-1	1.6	10.5	30.7	1	12.9	16.5	22	39.7	--	1.1	63.2	35.7	SICL	43	24
BNR-2	1.9	7	33	1	16	18.8	11.6	37.1	--	--	--	--	--	--	--
BNR-3	1.1	5.4	32.1	1	18.9	20.1	16	69.5	--	--	--	--	--	--	--
BNR-4	0.9	--	--	--	18.6	19.8	16.8	68.5	--	16.6	62	23.8	SIL	--	--
BNR-4	3.7	18.5	16.3	1	17.5	18.6	24.9	75.2	--	41	43.9	20.5	L	--	--
BNR-5	2.5	5.8	33	1	15.6	18.6	11.8	35.6	--	--	--	--	--	--	--
BNR-6	2	15.3	20.7	1	17.6	18.6	26.3	79.3	--	34.4	51.7	18.2	SIL	--	--
BNR-7	1.7	22.1	24.4	2	14.2	18.1	8	21.4	--	24	57.9	18.1	SIL	34	14
	4.7	19.8	30.1	2	18.4	19.6	17.6	68.4	--	42.4	39.4	19.3	L	--	--
BNR-8	1.5	19.7	20.8	2	18.2	19.2	22.9	78.8	--	24.7	48.5	29.1	CL	--	--
	4.3	10.2	26.4	2	18.5	19	27.3	89.8	--	16.8	49.4	35	SICL	--	--
BNR-9	2.2	44.1	17.7	3	19.3	19.7	22.8	89.5	--	11.5	49.3	39.2	SICL	--	--
	6.8	22.5	23.5	2	19	19.2	27.3	95	--	10.8	47.7	41.5	SIC	54	33
BNR-10	1.3	11.7	19.6	1	15.5	17.3	30.9	67.6	--	--	--	--	--	--	--
BNR-11	3	20.3	23.8	1	16.6	18	28.1	73	--	4.6	64.7	30.7	SICL	--	--
BNR-12	1.1	12.4	32.8	1	18.6	19.7	19.2	74.7	--	35.4	39.9	24.7	L	--	--
BNR-13	0.5	10.1	24.5	1	18.6	18.8	29.7	94.3	--	18.7	48.9	33.4	SICL	--	--
	1.6	21.3	27	3	--	--	--	--	--	16.5	53.4	30.2	SICL	--	--
BNR-14	2.2	14.3	35.7	1	16.9	18.4	23.5	67.9	--	14.4	61.6	24	SIL	--	--
	7.4	17.2	31.5	2	18.9	19	28.9	96.2	--	38.5	41.2	20.4	L	32	12
BNR-15	1.5	11.2	29.7	1	18.4	19.2	24	82.9	--	--	--	--	--	--	--

Table 3. Soil-property data from samples collected at study sites in eastern Nebraska, 1995 to 1999—Continued

					Soil unit weight (kN/m^3)				Particle-size distribution (%)				NASIS textural Class and modifier	Atterburg limits (%)	
Site ID	Sample depth (m)	c (kPa)	ϕ (°)	BST status	Ambient (γ_{amb})	Saturated (γ_{sat})	Moisture content (%)	Degree of saturation (%)	Gravel	Sand	Silt	Clay		Liquid limit	Plasticity index
Big Nemaha River Basin—Continued															
BNR-16	1.1	7.6	33.1	2	17.4	18.6	24.6	74	--	7.2	69.6	26	SIL	--	--
	4.8	--	--	--	17.7	18.7	24.8	77.2	--	1.9	50.8	50.4	SIC	--	--
BNR-17	1.3	18.6	9.4	3	17.5	18.3	29.9	83.3	--	2	45.4	57.3	SIC	--	--
	4.1	21.7	20	3	17.7	18.6	26	78.9	--	12.6	56.1	31.3	SICL	43	21
	5.9	7.8	24.3	1	16.9	17.8	33.8	83.6	--	12.3	46	42.3	SIC	--	--
Big Blue River Basin															
BBR-1	1.8	18	21.8	2	17.3	18.4	27.5	78.2	--	12.2	64.5	23.3	SIL	36	16
BBR-2	0.7	6.4	28.5	1	16	17.6	30.1	70.7	--	--	--	--	--	--	--
BBR-3	1.2	7.2	23.1	1	16.7	17.6	35.6	83.3	--	8.5	67.8	23.7	SIL	--	--
BBR-4	1.6	8.9	27.6	1	17.9	18.7	27.2	82.9	--	--	--	--	--	--	--
BBR-5	2.3	14.1	39.5	1	17.2	18.6	23.5	70.2	--	18.4	55.5	26.1	SIL	--	--
BBR-6	2.2	7	31.1	1	18.3	19.6	18.2	69.2	--	--	--	--	--	--	--
BBR-7	1.9	4.3	30.2	1	14.9	17.5	22.2	51.3	--	3.5	89.7	6.7	SIL	--	--
BBR-8	1	12.6	19	1	17.4	18.1	32	85.4	--	7.2	76.8	16	SIL	--	--
BBR-9	1.8	13.9	27.2	1	17.1	18.5	22.9	68	--	--	--	--	--	--	--
BBR-10	2	1.7	42.1	1	17.9	19.1	21.3	72.1	--	15.7	49.3	35.1	SICL	--	--
	4.7	3.3	32.9	2	18.8	19	28.2	94.7	--	31.1	55.1	13.8	SIL	--	--
BBR-11	1.8	10.8	29.7	1	13.3	17.1	15.3	32.1	--	4.5	69.1	26.4	SIL	--	--
BBR-12	1.7	12.7	29.5	1	18	19	23.6	77.4	--	--	--	--	--	--	--
BBR-13	2.3	2.3	38	2	15.1	18.5	9.9	29.1	--	29.1	54.6	16.3	SIL	--	--

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks

[ID, identification; kN/m^3, kilonewtons per cubic meter; kPa, kilopascals; ° , degrees; m, meters; CW*xx* , Channel-water level as a percentage (xx) of the bank height; BW*yy* , bank-water level as a percentage *(yy)* of bank height; F_s , Factor of safety; Soil group: 1, 2, 3, and 4 as referenced in text; %, percent; SS, Site specific soil property data used; *, Sites without site-specific soil property data or with site cohesion values of zero were analyzed using the median soil group data as needed. Indirect method: bh, bank height below range; ba, bank angle below range; c, cohesion above range;γsat, saturated soil unit weight above range; >, greater than; --, not applicable or no data; For each site reach, the average channel geometry and soil group median parameters were used, and for the individual bank sections within each reach, the section bank angles and the soil parameters for the site were used (all bank angles were weighted vertically); Summary results listed as or equivalent to the *at risk* condition are in bold font and those listed as or representing the unstable condition are in bold font and highlighted; Expected stable bank angles greater than the vertically weighted bank angles are shown in bold italics font]

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Missouri River Tributary Basins																			
MRT-1	2	16.4	17.9	10.8	28	45	3.1	38.9	36.7	5.9	4.7	Stable	Stable	4.0	1.9	--	2.4	1.5	***63***
	SS	18.1	18.7	13.7	29	53	4.6	24.6	22.0	5.9	4.4	Stable	**At Risk**	2.9	1.3	--	1.9	1.2	***60***
	SS	18.1	18.7	13.7	29	32	2.1	>50.0	>50.0	10.2	8.7	Stable	Stable	7.8	4.8	--	4.5	3.5	***90***
	SS	18.1	18.7	13.7	29	46	4.3	43.4	40.8	6.9	5.5	Stable	Stable	3.5	1.6	--	2.2	1.4	***63***
	SS	18.1	18.7	13.7	29	47	1.3	37.5	34.9	6.7	5.2	Stable	Stable	7.1	5.1	--	5.0	4.0	***90***
MRT-2	2	16.4	17.9	10.8	28	25	3.4	>50.0	>50.0	10.8	9.6	Stable	Stable	7.1	3.2	--	3.1	2.1	***61***
	SS	17.5	17.6	3.2	28	29	4.3	>50.0	>50.0	2.9	2.5	**At Risk**	**At Risk**	3.6	**0.7**	70.9	1.6	**0.8**	24
	SS	17.5	17.6	3.2	28	22	2.4	>50.0	>50.0	3.8	3.4	Stable	Stable	5.5	1.5	--	2.5	1.5	***34***
MRT-3	2	16.4	17.9	10.8	28	28	2.6	>50.0	>50.0	9.5	8.3	Stable	Stable	7.1	3.6	--	3.5	2.4	***80***
	SS	17.9	18.6	2.5	32	32	2.9	>50.0	>50.0	1.9	1.6	**At Risk**	**At Risk**	3.5	**0.6**	70.3	1.7	**0.9**	28
	SS	17.9	18.6	2.5	32	21	2.8	>50.0	>50.0	2.9	2.6	Stable	**At Risk**	5.5	1.0	--	2.5	1.4	***29***
	SS	17.9	18.6	2.5	32	28	2.9	>50.0	>50.0	2.2	1.9	**At Risk**	**At Risk**	4.1	**0.8**	75.7	2.0	**1.0**	***28***
	SS	17.9	18.6	2.5	32	31	2.4	>50.0	>50.0	1.9	1.7	**At Risk**	**At Risk**	3.8	**0.8**	77.0	1.9	**1.0**	***32***
	SS	17.9	18.6	2.5	32	35	2.8	>50.0	>50.0	1.7	1.4	**At Risk**	**At Risk**	3.2	**0.6**	67.2	1.7	**0.8**	29
	SS	17.9	18.6	2.5	32	23	2.2	>50.0	>50.0	2.6	2.4	Stable	Stable	5.3	1.2	--	2.6	1.5	***36***
MRT-4	2	16.4	17.9	10.8	28	46	7.8	33.0	30.8	5.6	4.4	**At Risk**	**At Risk**	2.6	**0.7**	70.2	1.5	**0.7**	34
	SS	18.0	19.2	4.8	31	35	8.0	>50.0	>50.0	3.2	2.7	**At Risk**	**At Risk**	2.9	**0.4**	57.9	1.5	**0.7**	26
	SS	18.0	19.2	4.8	31	53	8.1	10.0	9.0	2.0	1.5	**At Risk**	**At Risk**	1.8	**0.2**	44.2	**0.9**	**0.3**	26
	SS	18.0	19.2	4.8	31	30	7.9	>50.0	>50.0	3.7	3.2	**At Risk**	**At Risk**	3.4	**0.5**	61.9	1.6	**0.8**	26
	SS	18.0	19.2	4.8	31	58	8.0	7.1	6.1	1.8	1.3	**Unstable**	**Unstable**	1.6	**0.2**	39.6	**0.9**	**0.3**	26
	SS	18.0	19.2	4.8	31	44	7.1	22.7	21.8	2.5	2.0	**At Risk**	**At Risk**	2.3	**0.3**	52.6	1.2	**0.5**	26
	SS	18.0	19.2	4.8	31	58	7.8	7.1	6.1	1.8	1.3	**Unstable**	**Unstable**	1.6	**0.2**	39.9	**0.9**	**0.3**	26
MRT-5	2	16.4	17.9	10.8	28	49	5.0	25.5	23.3	5.3	4.0	Stable	**At Risk**	2.9	1.0	--	1.7	**1.0**	48
	2*	16.4	17.9	10.8	28	58	5.4	14.5	12.3	4.3	3.1	**At Risk**	**At Risk**	2.3	**0.8**	73.1	1.4	**0.7**	45
	2*	16.4	17.9	10.8	28	47	4.6	31.9	29.7	5.6	4.4	Stable	**At Risk**	3.2	1.2	--	1.9	1.1	***51***
	2*	16.4	17.9	10.8	28	43	5.1	44.5	42.3	6.1	4.9	Stable	**At Risk**	3.3	1.2	--	1.9	1.1	***47***
	2*	16.4	17.9	10.8	28	40	4.9	>50.0	>50.0	6.6	5.4	Stable	Stable	3.6	1.3	--	2.1	1.2	***49***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb} (kN/m^3)	Saturated soil unit weight, γ_{sat} (kN/m^3)	Effective cohesion, c' (kPa)	Friction angle, ϕ (°)	Vertically weighted bank angle (°)	Bank height (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Without tension cracks	With tension cracks	Ambient CW0--BW0 (F_S)	Saturated CW0--BW100 (F_S)	BWyy at which F_S = 1 for CW0 (%)	Ambient (F_S)	Saturated (F_S)	Maximum expected stable bank angle (saturated) (°)
Missouri River Tributary Basins--Continued																			
MRT-6	2	16.4	17.9	10.8	28	35	6.1	>50.0	>50.0	7.6	6.4	Stable	Stable	3.9	1.2	--	1.9	1.1	***39***
	SS	18.5	18.9	8.1	30	38	5.7	>50.0	>50.0	5.0	4.2	**At Risk**	**At Risk**	3.2	**0.9**	82.5	1.7	**1.0**	36
	SS	18.5	18.9	8.1	30	40	9.8	>50.0	>50.0	4.7	3.9	**At Risk**	**At Risk**	2.6	**0.5**	60.1	1.4	**0.7**	28
	SS	18.5	18.9	8.1	30	30	4.9	>50.0	>50.0	6.4	5.5	Stable	Stable	4.2	1.3	--	2.1	1.3	***41***
	SS	18.5	18.9	8.1	30	49	6.0	20.9	19.4	3.8	2.9	**At Risk**	**At Risk**	2.3	**0.6**	65.0	1.3	**0.6**	34
	SS	18.5	18.9	8.1	30	28	4.5	>50.0	>50.0	7.0	6.1	Stable	Stable	4.8	1.6	--	2.4	1.5	***44***
	SS	18.5	18.9	8.1	30	44	6.0	32.8	31.3	4.2	3.4	**At Risk**	**At Risk**	2.6	**0.7**	69.9	1.5	**0.7**	34
	SS	18.5	18.9	8.1	30	27	5.8	>50.0	>50.0	7.0	6.2	Stable	Stable	4.4	1.2	--	2.1	1.3	***35***
	SS	18.5	18.9	8.1	30	24	6.5	>50.0	>50.0	8.0	7.2	Stable	Stable	4.9	1.2	--	2.3	1.4	***33***
MRT-7	2	16.4	17.9	10.8	28	42	3.6	49.5	47.4	6.2	5.0	Stable	Stable	3.9	1.7	--	2.3	1.4	***59***
	SS	17.3	18.3	3.3	25	36	1.2	23.2	22.6	2.2	1.9	Stable	Stable	4.2	1.9	--	2.2	1.5	***63***
	SS	17.3	18.3	3.3	25	48	6.9	6.4	5.8	1.6	1.2	**Unstable**	**Unstable**	1.8	**0.2**	43.3	**0.8**	**0.3**	19
	SS	17.3	18.3	3.3	25	48	5.5	6.7	6.1	1.6	1.3	**At Risk**	**At Risk**	1.9	**0.3**	47.2	**0.9**	**0.3**	21
	SS	17.3	18.3	3.3	25	41	1.2	12.0	11.4	1.9	1.6	Stable	Stable	3.7	1.6	--	2.0	1.3	***63***
	SS	17.3	18.3	3.3	25	39	4.1	16.0	15.4	2.1	1.7	**At Risk**	**At Risk**	2.6	**0.5**	60.4	1.2	**0.6**	24
	SS	17.3	18.3	3.3	25	43	2.7	10.3	9.7	1.9	1.5	**At Risk**	**At Risk**	2.5	**0.7**	68.2	1.3	**0.7**	29
MRT-8	2	16.4	17.9	10.8	28	46	6.4	35.2	33.0	5.7	4.5	**At Risk**	**At Risk**	2.8	**0.9**	83.1	1.6	**0.8**	38
	SS	17.2	17.9	8.7	27	43	6.9	30.4	28.8	4.9	4.0	**At Risk**	**At Risk**	2.6	**0.7**	69.8	1.4	**0.7**	30
	SS	17.2	17.9	8.7	27	51	5.7	15.4	13.7	4.0	3.1	**At Risk**	**At Risk**	2.3	**0.7**	68.2	1.3	**0.7**	35
	SS	17.2	17.9	8.7	27	43	6.8	31.5	29.9	5.0	4.0	**At Risk**	**At Risk**	2.7	**0.7**	70.5	1.4	**0.7**	30
	SS	17.2	17.9	8.7	27	48	5.9	19.1	17.4	4.3	3.4	**At Risk**	**At Risk**	2.4	**0.7**	69.6	1.3	**0.7**	33
	SS	17.2	17.9	8.7	27	37	6.6	>50.0	>50.0	5.9	4.9	**At Risk**	**At Risk**	3.2	**0.9**	82.1	1.6	**0.9**	31
	SS	17.2	17.9	8.7	27	52	6.4	15.2	13.5	4.0	3.1	**At Risk**	**At Risk**	2.2	**0.6**	63.3	1.2	**0.6**	31
MRT-9	2	16.4	17.9	10.8	28	34	4.7	>50.0	>50.0	7.8	6.6	Stable	Stable	4.4	1.6	--	2.3	1.4	***50***
	SS	16.1	17.2	7.7	27	48	4.2	17.9	16.4	4.0	3.1	**At Risk**	**At Risk**	2.7	**0.9**	86.3	1.6	**0.9**	42
	SS	16.1	17.2	7.7	27	39	5.0	47.0	45.4	5.1	4.2	Stable	**At Risk**	3.3	1.0	--	1.7	**0.9**	37
	SS	16.1	17.2	7.7	27	39	4.0	46.3	44.8	5.1	4.2	Stable	Stable	3.5	1.3	--	1.9	1.1	***44***
	SS	16.1	17.2	7.7	27	36	5.2	>50.0	>50.0	5.6	4.7	Stable	**At Risk**	3.5	1.1	--	1.8	**1.0**	35
	SS	16.1	17.2	7.7	27	45	4.4	24.5	23.0	4.4	3.5	**At Risk**	**At Risk**	2.9	**1.0**	97.2	1.7	**0.9**	41
	SS	16.1	17.2	7.7	27	21	5.0	>50.0	>50.0	9.9	9.0	Stable	Stable	6.4	2.0	--	2.6	1.6	***37***
	SS	16.1	17.2	7.7	27	24	4.7	>50.0	>50.0	8.3	7.4	Stable	Stable	5.5	1.8	--	2.4	1.5	***39***
	SS	16.1	17.2	7.7	27	35	5.0	>50.0	>50.0	5.6	4.7	Stable	**At Risk**	3.6	1.1	--	1.9	**1.0**	***37***
	SS	16.1	17.2	7.7	27	30	5.0	>50.0	>50.0	6.8	5.9	Stable	Stable	4.4	1.3	--	2.0	1.2	***36***
	SS	16.1	17.2	7.7	27	40	5.0	41.2	39.6	4.9	4.0	**At Risk**	**At Risk**	3.2	**1.0**	91.7	1.7	**0.9**	36
	SS	16.1	17.2	7.7	27	34	4.8	>50.0	>50.0	5.8	4.9	Stable	Stable	3.8	1.2	--	1.9	1.1	***38***
	SS	16.1	17.2	7.7	27	31	5.1	>50.0	>50.0	6.4	5.5	Stable	Stable	4.1	1.3	--	2.0	1.1	***36***
	SS	16.1	17.2	7.7	27	44	3.9	27.1	25.5	4.5	3.6	Stable	**At Risk**	3.2	1.2	--	1.8	**1.0**	***45***
	SS	16.1	17.2	7.7	27	29	5.0	>50.0	>50.0	7.0	6.1	Stable	Stable	4.5	1.4	--	2.1	1.2	***37***
	SS	16.1	17.2	7.7	27	28	4.8	>50.0	>50.0	7.2	6.3	Stable	Stable	4.7	1.5	--	2.2	1.3	***38***
	SS	16.1	17.2	7.7	27	37	4.9	>50.0	>50.0	5.3	4.4	Stable	**At Risk**	3.4	1.1	--	1.8	**1.0**	37
	SS	16.1	17.2	7.7	27	39	4.3	48.8	47.3	5.1	4.2	Stable	**At Risk**	3.5	1.2	--	1.9	1.1	***42***
	SS	16.1	17.2	7.7	27	25	5.0	>50.0	>50.0	8.2	7.3	Stable	Stable	5.3	1.7	--	2.4	1.4	***37***
	SS	16.1	17.2	7.7	27	30	4.8	>50.0	>50.0	6.8	5.9	Stable	Stable	4.4	1.4	--	2.1	1.2	***38***
	SS	16.1	17.2	7.7	27	35	4.7	>50.0	>50.0	5.7	4.8	Stable	Stable	3.7	1.2	--	1.9	1.1	***39***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Missouri River Tributary Basins--Continued																			
MRT-10	2	16.4	17.9	10.8	28	46	9.1	33.7	31.5	5.7	4.5	**At Risk**	**At Risk**	2.5	**0.6**	64.4	1.4	**0.7**	31
	SS	16.4	18.4	11.6	35	30	8.6	>50.0	>50.0	9.4	8.1	Stable	**At Risk**	4.6	1.1	--	2.3	1.2	***39***
	SS	16.4	18.4	11.6	35	56	9.3	27.8	25.2	4.7	3.5	**At Risk**	**At Risk**	2.2	**0.5**	57.3	1.4	**0.5**	37
	SS	16.4	18.4	11.6	35	34	8.8	>50.0	>50.0	8.1	6.9	**At Risk**	**At Risk**	3.9	**0.9**	86.9	2.2	1.1	***38***
	SS	16.4	18.4	11.6	35	53	9.1	36.7	34.0	5.1	3.8	**At Risk**	**At Risk**	2.4	**0.6**	60.3	1.5	**0.6**	37
	SS	16.4	18.4	11.6	35	39	8.7	>50.0	>50.0	7.2	5.9	**At Risk**	**At Risk**	3.5	**0.8**	78.3	2.0	**1.0**	38
	SS	16.4	18.4	11.6	35	67	9.5	13.6	10.9	3.8	2.5	**At Risk**	**At Risk**	1.8	**0.4**	47.3	1.1	**0.3**	36
	SS	16.4	18.4	11.6	35	43	9.0	>50.0	>50.0	6.4	5.1	**At Risk**	**At Risk**	3.1	**0.7**	70.8	1.8	**0.8**	38
	SS	16.4	18.4	11.6	35	46	9.8	>50.0	>50.0	5.9	4.6	**At Risk**	**At Risk**	2.8	**0.6**	64.4	1.6	**0.7**	36
MRT-11	2	16.4	17.9	10.8	28	29	6.9	>50.0	>50.0	9.3	8.1	Stable	Stable	4.5	1.4	--	2.1	1.2	***37***
	SS	17.5	18.6	11.2	30	21	5.5	>50.0	>50.0	12.8	11.6	Stable	Stable	6.8	2.3	--	3.0	1.9	***46***
	SS	17.5	18.6	11.2	30	37	8.3	>50.0	>50.0	7.3	6.1	**At Risk**	**At Risk**	3.3	**0.9**	82.2	1.8	**1.0**	36
MRT-12	2	16.4	17.9	10.8	28	40	5.8	>50.0	>50.0	6.6	5.4	Stable	**At Risk**	3.4	1.1	--	1.8	**1.0**	***41***
	SS	17.7	18.7	10.7	28	43	6.0	41.8	39.8	5.8	4.7	**At Risk**	**At Risk**	2.9	**1.0**	90.7	1.6	**0.9**	39
	SS	17.7	18.7	10.7	28	46	5.7	31.8	29.7	5.4	4.3	**At Risk**	**At Risk**	2.8	**0.9**	88.5	1.6	**0.9**	41
	SS	17.7	18.7	10.7	28	46	5.8	32.6	30.6	5.5	4.3	**At Risk**	**At Risk**	2.8	**0.9**	88.6	1.6	**0.9**	41
	SS	17.7	18.7	10.7	28	41	5.6	>50.0	>50.0	6.1	5.0	Stable	**At Risk**	3.2	1.1	--	1.8	**1.0**	***42***
	SS	17.7	18.7	10.7	28	38	6.3	>50.0	>50.0	6.7	5.6	Stable	**At Risk**	3.4	1.1	--	1.8	**1.0**	***38***
	SS	17.7	18.7	10.7	28	53	5.4	18.1	16.1	4.6	3.4	**At Risk**	**At Risk**	2.4	**0.9**	78.7	1.5	**0.8**	44
	SS	17.7	18.7	10.7	28	25	7.7	>50.0	>50.0	10.2	9.0	Stable	Stable	4.8	1.3	--	2.2	1.3	***35***
	SS	17.7	18.7	10.7	28	29	4.1	>50.0	>50.0	8.8	7.6	Stable	Stable	5.3	2.2	--	2.6	1.7	***55***
MRT-13	2	16.4	17.9	10.8	28	30	3.1	>50.0	>50.0	8.9	7.7	Stable	Stable	6.2	2.9	--	2.9	1.9	***64***
	SS	16.9	17.9	7.7	24	21	3.0	>50.0	>50.0	9.4	8.6	Stable	Stable	7.3	3.2	--	2.7	1.9	***50***
	SS	16.9	17.9	7.7	24	34	2.9	>50.0	>50.0	5.6	4.8	Stable	Stable	4.4	1.9	--	2.2	1.4	***51***
	SS	16.9	17.9	7.7	24	27	3.6	>50.0	>50.0	7.1	6.2	Stable	Stable	5.0	2.0	--	2.3	1.5	***46***
	SS	16.9	17.9	7.7	24	39	2.7	32.1	30.7	4.9	4.0	Stable	Stable	3.9	1.8	--	2.2	1.5	***61***
MRT-15	2	16.4	17.9	10.8	28	36	5.1	>50.0	>50.0	7.5	6.3	Stable	Stable	4.1	1.5	--	2.2	1.3	***47***
	SS	16.9	18.3	13.5	27	33	4.7	>50.0	>50.0	10.1	8.6	Stable	Stable	5.0	2.1	--	2.6	1.7	***59***
	SS	16.9	18.3	13.5	27	32	5.2	>50.0	>50.0	10.3	8.8	Stable	Stable	4.8	2.0	--	2.4	1.5	***54***
	SS	16.9	18.3	13.5	27	42	5.1	>50.0	>50.0	7.8	6.3	Stable	Stable	3.7	1.5	--	2.1	1.3	***55***
	SS	16.9	18.3	13.5	27	36	5.2	>50.0	>50.0	9.1	7.6	Stable	Stable	4.3	1.8	--	2.3	1.5	***54***
MRT-16	2	16.4	17.9	10.8	28	30	6.8	>50.0	>50.0	9.1	7.9	Stable	Stable	4.4	1.3	--	2.1	1.2	***37***
	2*	16.4	17.9	10.8	28	26	6.8	>50.0	>50.0	10.7	9.4	Stable	Stable	5.2	1.6	--	2.3	1.4	***37***
	2*	16.4	17.9	10.8	28	24	8.9	>50.0	>50.0	11.3	10.1	Stable	Stable	5.1	1.3	--	2.3	1.3	***31***
	2*	16.4	17.9	10.8	28	35	6.4	>50.0	>50.0	7.7	6.5	Stable	Stable	3.8	1.2	--	1.9	1.1	***38***
	2*	16.4	17.9	10.8	28	35	6.9	>50.0	>50.0	7.6	6.4	Stable	**At Risk**	3.7	1.1	--	1.9	**1.0**	***37***
	2*	16.4	17.9	10.8	28	30	6.4	>50.0	>50.0	9.0	7.8	Stable	Stable	4.5	1.4	--	2.1	1.2	***38***
	2*	16.4	17.9	10.8	28	28	5.3	>50.0	>50.0	9.8	8.6	Stable	Stable	5.2	1.8	--	2.5	1.5	***45***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Missouri River Tributary Basins--Continued																			
MRT-17	2	16.4	17.9	10.8	28	53	5.4	20.3	18.1	4.9	3.7	**At Risk**	**At Risk**	2.6	**0.9**	82.9	1.6	**0.8**	44
	SS	18.6	19.0	16.0	28	28	3.9	>50.0	>50.0	13.5	11.8	Stable	Stable	6.6	3.5	--	3.2	2.3	***73***
	SS	18.6	19.0	16.0	28	53	6.1	24.4	21.6	6.7	5.0	Stable	**At Risk**	2.6	1.1	--	1.6	**1.0**	51
	SS	18.6	19.0	16.0	28	65	4.6	13.7	10.8	5.3	3.7	Stable	**At Risk**	2.3	1.2	--	1.7	**1.0**	***67***
	SS	18.6	19.0	16.0	28	59	5.8	17.9	15.1	6.0	4.3	Stable	**At Risk**	2.4	1.0	--	1.5	**0.9**	54
	SS	18.6	19.0	16.0	28	50	5.4	30.8	28.0	7.2	5.5	Stable	Stable	2.9	1.3	--	1.8	1.2	***58***
	SS	18.6	19.0	16.0	28	60	6.6	17.0	14.2	5.9	4.2	**At Risk**	**At Risk**	2.2	**0.9**	80.5	1.4	**0.8**	50
Papillion Creek Basin																			
PC-1	2	16.4	17.9	10.8	28	36	3.9	>50.0	>50.0	7.5	6.3	Stable	Stable	4.6	1.9	--	2.5	1.6	***57***
	SS	17.3	18.5	12.4	29	39	3.7	>50.0	>50.0	7.5	6.1	Stable	Stable	4.4	2.0	--	2.6	1.7	***64***
	SS	17.3	18.5	12.4	29	20	2.9	>50.0	>50.0	15.6	14.2	Stable	Stable	10.6	5.4	--	4.1	3.0	***75***
	SS	17.3	18.5	12.4	29	32	3.7	>50.0	>50.0	9.4	8.1	Stable	Stable	5.6	2.6	--	2.9	1.9	***64***
	SS	17.3	18.5	12.4	29	38	3.9	>50.0	>50.0	7.7	6.4	Stable	Stable	4.5	2.0	--	2.6	1.7	***62***
	SS	17.3	18.5	12.4	29	34	4.5	>50.0	>50.0	8.7	7.3	Stable	Stable	4.7	1.9	--	2.6	1.6	***57***
	SS	17.3	18.5	12.4	29	33	4.2	>50.0	>50.0	9.0	7.7	Stable	Stable	5.1	2.2	--	2.7	1.7	***60***
	SS	17.3	18.5	12.4	29	36	3.7	>50.0	>50.0	8.3	6.9	Stable	Stable	4.9	2.2	--	2.7	1.8	***64***
	SS	17.3	18.5	12.4	29	41	4.0	>50.0	>50.0	7.2	5.9	Stable	Stable	4.1	1.8	--	2.4	1.6	***61***
	SS	17.3	18.5	12.4	29	47	3.9	40.7	38.3	6.2	4.9	Stable	Stable	3.6	1.6	--	2.3	1.4	***63***
	SS	17.3	18.5	12.4	29	31	3.9	>50.0	>50.0	9.8	8.4	Stable	Stable	5.7	2.5	--	2.9	1.9	***63***
	SS	17.3	18.5	12.4	29	35	4.4	>50.0	>50.0	8.4	7.1	Stable	Stable	4.6	1.9	--	2.5	1.6	***58***
	SS	17.3	18.5	12.4	29	34	3.6	>50.0	>50.0	8.8	7.5	Stable	Stable	5.3	2.4	--	2.8	1.9	***64***
	SS	17.3	18.5	12.4	29	34	3.8	>50.0	>50.0	8.8	7.4	Stable	Stable	5.1	2.3	--	2.8	1.8	***63***
	SS	17.3	18.5	12.4	29	46	3.9	42.6	40.2	6.3	4.9	Stable	Stable	3.6	1.6	--	2.3	1.4	***62***
	SS	17.3	18.5	12.4	29	33	3.9	>50.0	>50.0	9.2	7.8	Stable	Stable	5.3	2.3	--	2.8	1.8	***62***
	SS	17.3	18.5	12.4	29	37	4.2	>50.0	>50.0	8.1	6.7	Stable	Stable	4.5	1.9	--	2.5	1.6	***60***
	SS	17.3	18.5	12.4	29	34	4.4	>50.0	>50.0	8.6	7.3	Stable	Stable	4.7	2.0	--	2.6	1.7	***58***
	SS	17.3	18.5	12.4	29	46	4.1	43.1	40.6	6.3	5.0	Stable	Stable	3.5	1.5	--	2.2	1.4	***61***
	SS	17.3	18.5	12.4	29	30	3.8	>50.0	>50.0	9.9	8.5	Stable	Stable	5.8	2.6	--	2.9	1.9	***63***
	SS	17.3	18.5	12.4	29	35	3.8	>50.0	>50.0	8.6	7.2	Stable	Stable	5.0	2.2	--	2.7	1.8	***63***
	SS	17.3	18.5	12.4	29	28	3.2	>50.0	>50.0	10.7	9.4	Stable	Stable	6.8	3.3	--	3.2	2.2	***67***
	SS	17.3	18.5	12.4	29	41	4.6	>50.0	>50.0	7.2	5.9	Stable	Stable	3.9	1.6	--	2.3	1.4	***57***
	SS	17.3	18.5	12.4	29	25	3.2	>50.0	>50.0	11.9	10.5	Stable	Stable	7.6	3.7	--	3.4	2.3	***67***
	SS	17.3	18.5	12.4	29	51	4.5	27.9	25.4	5.6	4.3	Stable	**At Risk**	3.0	1.2	--	1.9	1.1	***57***
	SS	17.3	18.5	12.4	29	25	3.8	>50.0	>50.0	12.1	10.8	Stable	Stable	7.2	3.2	--	3.3	2.2	***64***
	SS	17.3	18.5	12.4	29	42	3.6	>50.0	>50.0	6.9	5.6	Stable	Stable	4.1	1.9	--	2.5	1.6	***65***
	SS	17.3	18.5	12.4	29	51	4.0	26.8	24.3	5.6	4.2	Stable	Stable	3.2	1.4	--	2.1	1.3	***62***
	SS	17.3	18.5	12.4	29	20	4.0	>50.0	>50.0	15.4	14.1	Stable	Stable	8.8	3.8	--	3.6	2.5	***61***
	SS	17.3	18.5	12.4	29	20	4.1	>50.0	>50.0	15.3	14.0	Stable	Stable	8.7	3.8	--	3.6	2.5	***61***
	SS	17.3	18.5	12.4	29	47	3.9	38.9	36.4	6.1	4.8	Stable	Stable	3.5	1.6	--	2.2	1.4	***62***
	SS	17.3	18.5	12.4	29	25	3.1	>50.0	>50.0	11.8	10.5	Stable	Stable	7.8	3.8	--	3.5	2.4	***69***
	SS	17.3	18.5	12.4	29	38	4.1	>50.0	>50.0	7.8	6.4	Stable	Stable	4.4	1.9	--	2.5	1.6	***60***
	SS	17.3	18.5	12.4	29	34	3.1	>50.0	>50.0	8.7	7.3	Stable	Stable	5.7	2.8	--	3.0	2.0	***69***
	SS	17.3	18.5	12.4	29	51	4.3	27.3	24.8	5.6	4.2	Stable	**At Risk**	3.1	1.3	--	2.0	1.2	***59***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Papillion Creek Basin--Continued											
PC-2	2	16.4	17.9	10.8	28	42	5.1	>50.0	>50.0	6.3	5.1	Stable	Stable	3.4	1.2	--	2.0	1.1	***47***
	SS	14.9	17.4	13.5	28	46	6.2	46.6	43.6	7.3	5.7	Stable	**At Risk**	3.3	1.2	--	1.9	**1.0**	46
	SS	14.9	17.4	13.5	28	32	5.8	>50.0	>50.0	10.9	9.3	Stable	Stable	5.1	1.9	--	2.4	1.4	***48***
	SS	14.9	17.4	13.5	28	83	4.4	7.4	4.4	3.5	2.0	**At Risk**	**At Risk**	1.8	**0.8**	69.7	1.4	**0.5**	63
	SS	14.9	17.4	13.5	28	34	5.2	>50.0	>50.0	10.3	8.7	Stable	Stable	5.1	2.0	--	2.6	1.5	***55***
	SS	14.9	17.4	13.5	28	53	4.4	27.6	24.6	6.2	4.7	Stable	Stable	3.3	1.4	--	2.2	1.2	***63***
	SS	14.9	17.4	13.5	28	34	6.0	>50.0	>50.0	10.0	8.5	Stable	Stable	4.6	1.7	--	2.3	1.3	***46***
	SS	14.9	17.4	13.5	28	25	3.3	>50.0	>50.0	14.1	12.5	Stable	Stable	8.9	4.3	--	3.7	2.5	***72***
	SS	14.9	17.4	13.5	28	40	5.7	>50.0	>50.0	8.5	6.9	Stable	Stable	4.0	1.5	--	2.2	1.2	***49***
	SS	14.9	17.4	13.5	28	33	3.6	>50.0	>50.0	10.4	8.8	Stable	Stable	6.2	2.9	--	3.1	2.0	***69***
	SS	14.9	17.4	13.5	28	43	5.3	>50.0	>50.0	7.8	6.2	Stable	Stable	3.8	1.5	--	2.2	1.2	***53***
	SS	14.9	17.4	13.5	28	34	4.5	>50.0	>50.0	10.2	8.7	Stable	Stable	5.4	2.3	--	2.8	1.7	***62***
	SS	14.9	17.4	13.5	28	37	5.5	>50.0	>50.0	9.2	7.6	Stable	Stable	4.4	1.7	--	2.4	1.4	***51***
	SS	14.9	17.4	13.5	28	26	5.3	>50.0	>50.0	13.5	12.0	Stable	Stable	6.6	2.5	--	2.9	1.8	***53***
	SS	14.9	17.4	13.5	28	49	5.7	35.8	32.8	6.8	5.2	Stable	**At Risk**	3.2	1.2	--	1.9	**1.0**	***50***
	SS	14.9	17.4	13.5	28	44	6.0	>50.0	>50.0	7.6	6.1	Stable	Stable	3.5	1.3	--	2.0	1.1	***47***
	SS	14.9	17.4	13.5	28	28	5.7	>50.0	>50.0	12.6	11.1	Stable	Stable	6.0	2.2	--	2.7	1.6	***49***
	SS	14.9	17.4	13.5	28	37	3.3	>50.0	>50.0	9.3	7.7	Stable	Stable	5.8	2.8	--	3.1	2.0	***72***
	SS	14.9	17.4	13.5	28	59	5.4	18.8	15.7	5.4	3.9	Stable	**At Risk**	2.6	1.0	--	1.7	**0.8**	52
	SS	14.9	17.4	13.5	28	67	4.8	13.2	10.2	4.7	3.1	**At Risk**	**At Risk**	2.4	**1.0**	92.1	1.7	**0.8**	58
	SS	14.9	17.4	13.5	28	29	5.5	>50.0	>50.0	12.0	10.5	Stable	Stable	5.8	2.2	--	2.7	1.6	***51***
PC-3	2	16.4	17.9	10.8	28	31	3.5	>50.0	>50.0	8.6	7.4	Stable	Stable	5.6	2.5	--	2.7	1.8	***61***
	SS	17.2	18.3	12.3	23	38	4.0	>50.0	48.7	7.9	6.5	Stable	Stable	4.2	2.0	--	2.3	1.5	***61***
	SS	17.2	18.3	12.3	23	25	3.2	>50.0	>50.0	12.1	10.8	Stable	Stable	7.2	3.8	--	3.0	2.2	***68***
	SS	17.2	18.3	12.3	23	23	3.9	>50.0	>50.0	13.0	11.6	Stable	Stable	7.0	3.3	--	2.9	2.1	***62***
	SS	17.2	18.3	12.3	23	24	3.5	>50.0	>50.0	12.8	11.5	Stable	Stable	7.2	3.6	--	3.0	2.1	***65***
	SS	17.2	18.3	12.3	23	27	3.2	>50.0	>50.0	11.2	9.9	Stable	Stable	6.6	3.5	--	2.9	2.0	***68***
	SS	17.2	18.3	12.3	23	51	2.9	18.2	16.0	5.7	4.3	Stable	Stable	3.5	1.9	--	2.2	1.5	***72***
PC-4	2	16.4	17.9	10.8	28	46	8.0	34.9	32.8	5.7	4.5	**At Risk**	**At Risk**	2.6	**0.7**	69.7	1.5	**0.7**	34
	SS	14.2	17.5	11.5	36	52	8.0	>50.0	49.6	5.3	4.0	**At Risk**	**At Risk**	2.8	**0.7**	67.2	1.7	**0.7**	40
	SS	14.2	17.5	11.5	36	45	8.0	>50.0	>50.0	6.4	5.0	**At Risk**	**At Risk**	3.4	**0.8**	76.1	2.0	**0.9**	40
	SS	14.2	17.5	11.5	36	44	7.5	>50.0	>50.0	6.6	5.3	**At Risk**	**At Risk**	3.6	**0.9**	82.5	2.1	**0.9**	41
	SS	14.2	17.5	11.5	36	35	7.8	>50.0	>50.0	8.4	7.1	Stable	**At Risk**	4.5	1.1	--	2.4	1.2	***40***
	SS	14.2	17.5	11.5	36	63	8.3	22.6	19.4	4.3	3.0	**At Risk**	**At Risk**	2.2	**0.5**	56.4	1.4	**0.4**	39
	SS	14.2	17.5	11.5	36	36	8.3	>50.0	>50.0	8.1	6.8	**At Risk**	**At Risk**	4.3	**1.0**	93.4	2.3	1.1	***39***
PC-5	2	16.4	17.9	10.8	28	27	8.4	>50.0	>50.0	9.9	8.7	Stable	Stable	4.5	1.2	--	2.1	1.2	***33***
	SS	17.7	18.6	14.5	25	35	8.7	>50.0	>50.0	9.9	8.4	Stable	**At Risk**	3.5	1.1	--	1.8	1.1	***39***
	SS	17.7	18.6	14.5	25	33	8.4	>50.0	>50.0	10.6	9.0	Stable	Stable	3.7	1.3	--	1.9	1.1	***40***
	SS	17.7	18.6	14.5	25	19	7.9	>50.0	>50.0	18.7	17.1	Stable	Stable	6.8	2.4	--	2.6	1.7	***41***
	SS	17.7	18.6	14.5	25	29	8.4	>50.0	>50.0	11.9	10.3	Stable	Stable	4.2	1.4	--	2.0	1.2	***40***
	SS	17.7	18.6	14.5	25	24	8.7	>50.0	>50.0	14.7	13.2	Stable	Stable	5.1	1.7	--	2.3	1.5	***38***
	SS	17.7	18.6	14.5	25	24	8.6	>50.0	>50.0	14.6	13.1	Stable	Stable	5.1	1.7	--	2.3	1.5	***39***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Papillion Creek Basin--Continued																			
PC-7	2	16.4	17.9	10.8	28	34	7.4	>50.0	>50.0	7.9	6.7	Stable	**At Risk**	3.7	1.1	--	1.9	**1.0**	***36***
	SS	17.2	17.9	11.4	21	29	7.5	>50.0	>50.0	10.0	8.7	Stable	Stable	3.9	1.3	--	1.7	1.1	***31***
	SS	17.2	17.9	11.4	21	39	7.6	30.0	28.1	7.2	5.9	**At Risk**	**At Risk**	2.8	**0.9**	86.8	1.4	**0.8**	30
	SS	17.2	17.9	11.4	21	29	7.4	>50.0	>50.0	9.9	8.6	Stable	Stable	3.9	1.3	--	1.7	1.1	***31***
	SS	17.2	17.9	11.4	21	29	7.4	>50.0	>50.0	10.0	8.7	Stable	Stable	3.9	1.3	--	1.7	1.1	***31***
	SS	17.2	17.9	11.4	21	37	7.5	36.1	34.2	7.6	6.3	Stable	**At Risk**	3.0	1.0	--	1.5	**0.9**	30
	SS	17.2	17.9	11.4	21	41	7.1	25.5	23.6	6.8	5.5	**At Risk**	**At Risk**	2.7	**1.0**	88.2	1.4	**0.8**	32
PC-8	2	16.4	17.9	10.8	28	44	7.5	41.8	39.7	6.0	4.8	**At Risk**	**At Risk**	2.8	**0.8**	75.1	1.6	**0.8**	35
	SS	17.9	18.3	7.6	26	46	7.8	17.7	16.3	3.9	3.0	**At Risk**	**At Risk**	2.2	**0.5**	58.1	1.2	**0.6**	27
	SS	17.9	18.3	7.6	26	40	7.6	34.0	32.6	4.6	3.8	**At Risk**	**At Risk**	2.6	**0.6**	64.6	1.3	**0.7**	27
	SS	17.9	18.3	7.6	26	37	8.0	>50.0	48.9	5.0	4.1	**At Risk**	**At Risk**	2.8	**0.6**	66.9	1.4	**0.7**	27
	SS	17.9	18.3	7.6	26	45	7.8	19.3	18.0	4.0	3.1	**At Risk**	**At Risk**	2.2	**0.5**	59.1	1.2	**0.6**	27
	SS	17.9	18.3	7.6	26	36	8.1	>50.0	>50.0	5.2	4.3	**At Risk**	**At Risk**	2.9	**0.6**	67.7	1.4	**0.8**	27
	SS	17.9	18.3	7.6	26	45	7.1	20.3	18.9	4.0	3.2	**At Risk**	**At Risk**	2.3	**0.6**	62.1	1.2	**0.6**	28
	SS	17.9	18.3	7.6	26	58	7.9	8.6	7.3	3.0	2.2	**At Risk**	**Unstable**	1.7	**0.4**	46.3	**0.9**	**0.4**	27
	SS	17.9	18.3	7.6	26	44	7.5	20.7	19.3	4.1	3.2	**At Risk**	**At Risk**	2.3	**0.5**	60.7	1.2	**0.6**	28
	SS	17.9	18.3	7.6	26	40	7.0	31.3	30.0	4.5	3.7	**At Risk**	**At Risk**	2.6	**0.6**	66.4	1.4	**0.7**	28
	SS	17.9	18.3	7.6	26	47	6.2	16.4	15.0	3.8	3.0	**At Risk**	**At Risk**	2.2	**0.6**	63.4	1.2	**0.6**	29
PC-9	2	16.4	17.9	10.8	28	38	3.7	>50.0	>50.0	7.0	5.8	Stable	Stable	4.4	1.9	--	2.4	1.5	***58***
	SS	15.8	17.4	24.0	22	40	4.0	>50.0	>50.0	15.2	12.5	Stable	Stable	6.2	3.8	--	3.5	2.6	***90***
	SS	15.8	17.4	24.0	22	26	3.6	>50.0	>50.0	23.9	21.1	Stable	Stable	10.5	6.7	--	4.4	3.3	***90***
	SS	15.8	17.4	24.0	22	25	3.5	>50.0	>50.0	24.9	22.1	Stable	Stable	11.1	7.1	--	4.5	3.4	***90***
	SS	15.8	17.4	24.0	22	61	4.0	22.3	17.8	9.4	6.7	Stable	Stable	3.8	2.4	--	2.8	2.0	***90***
	SS	15.8	17.4	24.0	22	39	3.7	>50.0	>50.0	15.4	12.7	Stable	Stable	6.6	4.2	--	3.7	2.7	***90***
	SS	15.8	17.4	24.0	22	38	3.7	>50.0	>50.0	16.0	13.2	Stable	Stable	6.8	4.3	--	3.7	2.8	***90***
PC-10	2	16.4	17.9	10.8	28	34	3.8	>50.0	>50.0	7.9	6.7	Stable	Stable	4.9	2.1	--	2.6	1.6	***58***
	SS	17.2	18.2	9.2	26	27	3.7	>50.0	>50.0	8.3	7.3	Stable	Stable	5.4	2.3	--	2.5	1.7	***52***
	SS	17.2	18.2	9.2	26	42	3.5	34.9	33.2	5.3	4.3	Stable	Stable	3.6	1.5	--	2.0	1.3	***53***
	SS	17.2	18.2	9.2	26	43	3.4	31.3	29.6	5.2	4.2	Stable	Stable	3.5	1.5	--	2.0	1.3	***54***
	SS	17.2	18.2	9.2	26	21	3.6	>50.0	>50.0	11.0	10.0	Stable	Stable	7.3	3.0	--	2.9	2.0	***52***
	SS	17.2	18.2	9.2	26	36	4.3	>50.0	>50.0	6.2	5.2	Stable	Stable	3.8	1.4	--	2.0	1.3	***47***
	SS	17.2	18.2	9.2	26	34	4.3	>50.0	>50.0	6.5	5.5	Stable	Stable	4.0	1.5	--	2.1	1.3	***47***
PC-11	2	16.4	17.9	10.8	28	38	6.1	>50.0	>50.0	7.0	5.8	Stable	**At Risk**	3.5	1.1	--	1.8	**1.0**	***39***
	SS	18.5	19.3	8.9	24	39	5.6	32.1	30.6	5.2	4.3	**At Risk**	**At Risk**	2.9	**0.9**	87.9	1.5	**0.9**	34
	SS	18.5	19.3	8.9	24	34	6.7	>50.0	>50.0	6.0	5.0	**At Risk**	**At Risk**	3.1	**0.9**	83.7	1.5	**0.9**	29
	SS	18.5	19.3	8.9	24	28	5.5	>50.0	>50.0	7.3	6.4	Stable	Stable	4.1	1.3	--	1.9	1.2	***35***
	SS	18.5	19.3	8.9	24	51	6.8	12.5	11.1	3.9	3.0	**At Risk**	**At Risk**	2.0	**0.6**	61.5	1.1	**0.6**	29
	SS	18.5	19.3	8.9	24	38	5.6	36.0	34.6	5.4	4.5	**At Risk**	**At Risk**	3.0	**1.0**	90.9	1.5	**0.9**	34
	SS	18.5	19.3	8.9	24	39	6.6	32.7	31.3	5.3	4.3	**At Risk**	**At Risk**	2.7	**0.8**	77.2	1.4	**0.8**	30

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, *c′*	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which $F_S = 1$ for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Papillion Creek Basin--Continued																			
PC-12	2	16.4	17.9	10.8	28	38	5.2	>50.0	>50.0	7.1	5.9	Stable	Stable	3.8	1.4	--	2.1	1.2	***47***
	SS	15.8	17.1	4.5	29	36	4.9	>50.0	>50.0	3.2	2.7	**At Risk**	**At Risk**	3.2	**0.7**	68.1	1.6	**0.7**	27
	SS	15.8	17.1	4.5	29	37	5.1	>50.0	>50.0	3.2	2.7	**At Risk**	**At Risk**	3.1	**0.6**	66.4	1.5	**0.7**	26
	SS	15.8	17.1	4.5	29	34	5.3	>50.0	>50.0	3.4	2.9	**At Risk**	**At Risk**	3.3	**0.7**	68.2	1.6	**0.7**	26
	SS	15.8	17.1	4.5	29	40	5.2	32.1	31.1	2.9	2.3	**At Risk**	**At Risk**	2.8	**0.5**	61.6	1.4	**0.6**	26
	SS	15.8	17.1	4.5	29	34	4.9	>50.0	>50.0	3.4	2.9	**At Risk**	**At Risk**	3.4	**0.7**	70.6	1.6	**0.8**	27
	SS	15.8	17.1	4.5	29	47	5.3	14.4	13.4	2.4	1.9	**At Risk**	**At Risk**	2.3	**0.5**	55.4	1.2	**0.5**	26
	SS	15.8	17.1	4.5	29	34	5.0	>50.0	>50.0	3.5	2.9	**At Risk**	**At Risk**	3.4	**0.7**	70.6	1.6	**0.8**	26
	SS	15.8	17.1	4.5	29	39	5.4	39.4	38.4	3.0	2.4	**At Risk**	**At Risk**	2.8	**0.5**	62.0	1.4	**0.6**	25
Platte River Tributary Basins																			
PRT-1	2	16.4	17.9	10.8	28	38	4.9	>50.0	>50.0	7.1	5.9	Stable	Stable	3.9	1.5	--	2.2	1.3	***49***
	2*	16.4	17.9	10.8	28	46	4.0	32.4	30.2	5.6	4.4	Stable	Stable	3.4	1.4	--	2.1	1.2	***56***
	2*	16.4	17.9	10.8	28	32	4.2	>50.0	>50.0	8.5	7.3	Stable	Stable	5.0	2.0	--	2.5	1.6	***55***
	2*	16.4	17.9	10.8	28	44	5.4	41.6	39.4	6.0	4.8	Stable	**At Risk**	3.2	1.1	--	1.8	**1.0**	***44***
	2*	16.4	17.9	10.8	28	34	4.5	>50.0	>50.0	7.9	6.7	Stable	Stable	4.5	1.8	--	2.4	1.5	***52***
	2*	16.4	17.9	10.8	28	40	5.9	>50.0	>50.0	6.7	5.5	Stable	**At Risk**	3.4	1.1	--	1.8	**1.0**	***40***
	2*	16.4	17.9	10.8	28	31	5.1	>50.0	>50.0	8.8	7.6	Stable	Stable	4.8	1.7	--	2.3	1.4	***47***
PRT-2	2	16.4	17.9	10.8	28	37	5.4	>50.0	>50.0	7.3	6.1	Stable	Stable	3.9	1.3	--	2.1	1.2	***44***
	SS	14.0	17.6	12.3	31	38	4.6	>50.0	>50.0	8.1	6.7	Stable	Stable	4.9	1.8	--	2.7	1.5	***57***
	SS	14.0	17.6	12.3	31	28	6.0	>50.0	>50.0	11.2	9.8	Stable	Stable	5.9	1.8	--	2.7	1.5	***44***
	SS	14.0	17.6	12.3	31	46	4.3	>50.0	>50.0	6.6	5.2	Stable	Stable	4.1	1.5	--	2.5	1.4	***59***
	SS	14.0	17.6	12.3	31	35	6.7	>50.0	>50.0	9.0	7.6	Stable	Stable	4.6	1.3	--	2.3	1.2	***42***
PRT-3	2	16.4	17.9	10.8	28	40	3.0	>50.0	>50.0	6.7	5.5	Stable	Stable	4.7	2.3	--	2.6	1.7	***66***
	2*	16.4	17.9	10.8	28	40	3.0	>50.0	>50.0	6.6	5.4	Stable	Stable	4.6	2.2	--	2.6	1.7	***66***
	2*	16.4	17.9	10.8	28	43	3.0	45.1	42.9	6.1	4.9	Stable	Stable	4.3	2.1	--	2.5	1.6	***65***
	2*	16.4	17.9	10.8	28	34	2.9	>50.0	>50.0	7.8	6.6	Stable	Stable	5.5	2.7	--	2.8	1.9	***67***
	2*	16.4	17.9	10.8	28	35	2.9	>50.0	>50.0	7.6	6.4	Stable	Stable	5.4	2.6	--	2.9	1.9	***69***
	2*	16.4	17.9	10.8	28	50	2.9	24.0	21.8	5.2	3.9	Stable	Stable	3.6	1.8	--	2.3	1.4	***67***
	2*	16.4	17.9	10.8	28	30	3.0	>50.0	>50.0	9.1	7.9	Stable	Stable	6.4	3.1	--	3.0	2.0	***66***
	2*	16.4	17.9	10.8	28	40	3.0	>50.0	>50.0	6.7	5.5	Stable	Stable	4.6	2.2	--	2.6	1.6	***64***
	2*	16.4	17.9	10.8	28	44	3.0	43.0	40.8	6.0	4.8	Stable	Stable	4.2	2.0	--	2.4	1.5	***64***
PRT-4	2	16.4	17.9	10.8	28	45	3.1	38.5	36.3	5.9	4.7	Stable	Stable	4.0	1.9		2.4	1.5	***64***
	SS	17.9	18.6	4.2	28	51	2.6	8.1	7.3	1.9	1.5	**At Risk**	**At Risk**	2.3	**0.7**	69.8	1.4	**0.7**	39
	SS	17.9	18.6	4.2	28	44	2.7	14.4	13.6	2.3	1.8	**At Risk**	**At Risk**	2.7	**0.8**	77.4	1.5	**0.9**	37
	SS	17.9	18.6	4.2	28	50	3.1	8.3	7.5	1.9	1.5	**At Risk**	**At Risk**	2.2	**0.6**	63.8	1.2	**0.6**	30
	SS	17.9	18.6	4.2	28	40	3.2	22.5	21.8	2.5	2.0	**At Risk**	**At Risk**	2.8	**0.8**	75.2	1.5	**0.8**	30
	SS	17.9	18.6	4.2	28	39	3.2	28.0	27.3	2.6	2.1	**At Risk**	**At Risk**	3.0	**0.8**	76.3	1.5	**0.8**	30
	SS	17.9	18.6	4.2	28	43	3.3	15.6	14.8	2.3	1.8	**At Risk**	**At Risk**	2.6	**0.7**	68.9	1.4	**0.7**	30
	SS	17.9	18.6	4.2	28	46	3.0	11.6	10.9	2.1	1.7	**At Risk**	**At Risk**	2.5	**0.7**	69.5	1.3	**0.7**	31
	SS	17.9	18.6	4.2	28	45	3.3	12.3	11.6	2.2	1.7	**At Risk**	**At Risk**	2.5	**0.7**	66.9	1.3	**0.6**	30

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Platte River Tributary Basins--Continued																			
PRT-5	3	16.5	18.1	6.7	30	53	9.1	14.2	12.8	2.9	2.2	**At Risk**	**At Risk**	1.9	**0.3**	47.9	**1.0**	**0.4**	27
	SS	15.2	18.3	7.1	30	43	8.3	45.9	44.3	4.0	3.2	**At Risk**	**At Risk**	2.7	**0.5**	58.9	1.4	**0.6**	28
	SS	15.2	18.3	7.1	30	58	9.8	11.9	10.2	2.8	2.0	**At Risk**	**At Risk**	1.8	**0.3**	44.4	**1.0**	**0.3**	27
	SS	15.2	18.3	7.1	30	39	9.1	>50.0	>50.0	4.3	3.6	**At Risk**	**At Risk**	2.9	**0.5**	60.0	1.5	**0.7**	27
	SS	15.2	18.3	7.1	30	60	9.5	10.4	8.8	2.7	1.9	**At Risk**	**Unstable**	1.7	**0.3**	42.9	**1.0**	**0.3**	27
	SS	15.2	18.3	7.1	30	61	9.0	10.2	8.6	2.7	1.9	**At Risk**	**Unstable**	1.8	**0.3**	43.6	**1.0**	**0.3**	27
	SS	15.2	18.3	7.1	30	58	8.9	11.6	10.0	2.8	2.0	**At Risk**	**At Risk**	1.8	**0.3**	45.8	**1.0**	**0.3**	28
PRT-6	3	16.5	18.1	6.7	30	38	5.9	>50.0	>50.0	4.3	3.6	**At Risk**	**At Risk**	3.2	**0.7**	72.5	1.7	**0.8**	30
	SS	17.2	18.5	15.8	29	27	4.9	>50.0	>50.0	14.0	12.3	Stable	Stable	6.4	2.9	--	3.1	2.1	***64***
	SS	17.2	18.5	15.8	29	41	7.8	>50.0	>50.0	9.1	7.4	Stable	**At Risk**	3.4	1.2	--	2.0	1.1	***47***
	SS	17.2	18.5	15.8	29	30	4.6	>50.0	>50.0	12.9	11.2	Stable	Stable	6.1	2.8	--	3.1	2.0	***67***
	SS	17.2	18.5	15.8	29	46	6.6	>50.0	>50.0	8.1	6.3	Stable	**At Risk**	3.2	1.2	--	1.9	1.1	***50***
	SS	17.2	18.5	15.8	29	30	5.0	>50.0	>50.0	12.8	11.1	Stable	Stable	5.8	2.6	--	2.9	1.9	***63***
	SS	17.2	18.5	15.8	29	51	6.4	34.2	31.0	7.1	5.4	Stable	**At Risk**	2.9	1.1	--	1.7	**1.0**	50
PRT-7	1	15.9	17.6	13.6	26	54	6.1	21.3	18.6	6.1	4.5	**At Risk**	**At Risk**	2.6	**1.0**	100.0	1.5	**0.8**	45
	SS	15.4	17.8	12.8	30	54	6.2	26.6	23.8	5.7	4.3	**At Risk**	**At Risk**	2.7	**0.9**	84.5	1.6	**0.8**	45
	SS	15.4	17.8	12.8	30	58	6.2	20.8	18.0	5.2	3.8	**At Risk**	**At Risk**	2.5	**0.8**	77.3	1.5	**0.7**	44
	SS	15.4	17.8	12.8	30	52	6.0	29.3	26.4	5.9	4.4	**At Risk**	**At Risk**	2.8	**1.0**	94.9	1.7	**0.8**	45
	SS	15.4	17.8	12.8	30	49	6.0	39.6	36.7	6.4	4.9	Stable	**At Risk**	3.1	1.1	--	1.8	**0.9**	45
	SS	15.4	17.8	12.8	30	58	6.2	20.7	17.8	5.2	3.8	**At Risk**	**At Risk**	2.5	**0.8**	77.7	1.5	**0.7**	45
	SS	15.4	17.8	12.8	30	54	5.9	26.1	23.3	5.7	4.2	**At Risk**	**At Risk**	2.7	**1.0**	89.6	1.6	**0.8**	46
PRT-8	1	15.9	17.6	13.6	26	39	4.0	>50.0	>50.0	8.7	7.2	Stable	Stable	4.6	2.2	--	2.6	1.7	***67***
	SS	16.4	18.0	16.9	25	39	3.7	>50.0	>50.0	10.5	8.7	Stable	Stable	5.2	2.8	--	3.0	2.1	***78***
	SS	16.4	18.0	16.9	25	35	4.5	>50.0	>50.0	11.9	10.0	Stable	Stable	5.2	2.6	--	2.8	1.9	***71***
	SS	16.4	18.0	16.9	25	42	3.6	>50.0	>50.0	9.7	7.9	Stable	Stable	4.9	2.7	--	2.9	2.0	***79***
	SS	16.4	18.0	16.9	25	39	4.1	>50.0	>50.0	10.5	8.7	Stable	Stable	5.0	2.6	--	2.8	1.9	***75***
PRT-9	2	16.4	17.9	10.8	28	51	6.1	22.0	19.8	5.0	3.8	**At Risk**	**At Risk**	2.5	**0.8**	76.4	1.4	**0.7**	39
	SS	15.9	17.7	4.5	33	53	6.1	12.3	11.3	2.0	1.5	**At Risk**	**At Risk**	2.1	**0.3**	48.7	1.1	**0.3**	26
	SS	15.9	17.7	4.5	33	56	6.1	9.6	8.5	1.9	1.4	**At Risk**	**At Risk**	1.9	**0.3**	46.5	**1.0**	**0.3**	26
	SS	15.9	17.7	4.5	33	43	5.8	46.2	45.1	2.6	2.1	**At Risk**	**At Risk**	2.7	**0.5**	57.4	1.4	**0.5**	27
	SS	15.9	17.7	4.5	33	53	6.3	12.5	11.4	2.0	1.5	**At Risk**	**At Risk**	2.1	**0.3**	48.4	1.1	**0.3**	26
PRT-10	2	16.4	17.9	10.8	28	34	6.2	>50.0	>50.0	7.9	6.7	Stable	Stable	4.0	1.3	--	2.0	1.1	***39***
	SS	17.0	18.3	6.5	29	24	6.4	>50.0	>50.0	6.7	6.0	Stable	**At Risk**	4.9	1.1	--	2.2	1.2	***28***
	SS	17.0	18.3	6.5	29	38	6.7	>50.0	>50.0	4.1	3.4	**At Risk**	**At Risk**	2.9	**0.6**	66.3	1.5	**0.7**	28
	SS	17.0	18.3	6.5	29	43	6.4	29.9	28.6	3.6	2.9	**At Risk**	**At Risk**	2.6	**0.6**	61.9	1.4	**0.6**	28
	SS	17.0	18.3	6.5	29	31	5.5	>50.0	>50.0	5.1	4.4	**At Risk**	**At Risk**	3.8	**0.9**	87.3	1.8	**1.0**	31
PRT-11	2	16.4	17.9	10.8	28	42	6.0	>50.0	47.9	6.2	5.0	Stable	**At Risk**	3.2	1.0	--	1.7	**0.9**	39
	SS	17.2	17.8	14.0	22	61	5.5	11.8	9.4	5.4	3.8	**At Risk**	**At Risk**	2.1	**1.0**	89.4	1.4	**0.8**	50
	SS	17.2	17.8	14.0	22	31	5.3	>50.0	>50.0	11.3	9.7	Stable	Stable	4.6	2.1	--	2.2	1.5	***53***
	SS	17.2	17.8	14.0	22	28	8.2	>50.0	>50.0	12.4	10.8	Stable	Stable	4.2	1.5	--	1.9	1.2	***37***
	SS	17.2	17.8	14.0	22	49	5.1	20.4	18.0	6.9	5.3	Stable	Stable	2.9	1.4	--	1.7	1.1	***55***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Platte River Tributary Basins--Continued											
PRT-12	2	16.4	17.9	10.8	28	44	6.6	42.3	40.2	6.0	4.8	**At Risk**	**At Risk**	2.9	**0.9**	83.5	1.6	**0.9**	38
	SS	17.6	18.3	4.7	25	37	6.8	24.7	23.9	3.1	2.5	**At Risk**	**At Risk**	2.5	**0.5**	58.7	1.2	**0.6**	22
	SS	17.6	18.3	4.7	25	47	6.4	9.3	8.5	2.4	1.8	**At Risk**	**At Risk**	2.0	**0.4**	51.2	**0.9**	**0.4**	22
	SS	17.6	18.3	4.7	25	47	6.7	9.3	8.5	2.4	1.8	**At Risk**	**At Risk**	1.9	**0.4**	50.1	**0.9**	**0.4**	22
	SS	17.6	18.3	4.7	25	38	6.5	21.3	20.5	3.0	2.4	**At Risk**	**At Risk**	2.5	**0.5**	58.4	1.1	**0.5**	22
	SS	17.6	18.3	4.7	25	51	6.6	7.3	6.5	2.2	1.6	**At Risk**	**Unstable**	1.8	**0.3**	46.7	**0.8**	**0.3**	22
	SS	17.6	18.3	4.7	25	42	6.8	14.2	13.4	2.7	2.2	**At Risk**	**At Risk**	2.2	**0.4**	54.4	**1.0**	**0.5**	22
PRT-13	2	16.4	17.9	10.8	28	48	5.2	29.3	27.1	5.5	4.3	Stable	**At Risk**	2.9	1.1	--	1.7	**1.0**	47
	SS	15.7	17.2	6.0	25	50	5.1	11.6	10.4	3.0	2.3	**At Risk**	**At Risk**	2.2	**0.6**	61.6	1.2	**0.5**	28
	SS	15.7	17.2	6.0	25	57	5.4	7.8	6.6	2.6	1.9	**At Risk**	**At Risk**	1.9	**0.5**	53.4	**1.0**	**0.4**	27
	SS	15.7	17.2	6.0	25	39	5.2	29.2	28.0	3.9	3.2	**At Risk**	**At Risk**	2.9	**0.8**	72.7	1.5	**0.7**	28
	SS	15.7	17.2	6.0	25	56	5.3	8.0	6.8	2.6	1.9	**At Risk**	**At Risk**	1.9	**0.5**	54.1	**1.0**	**0.4**	27
	SS	15.7	17.2	6.0	25	41	5.0	24.3	23.1	3.8	3.1	**At Risk**	**At Risk**	2.8	**0.7**	72.1	1.4	**0.7**	28
	SS	15.7	17.2	6.0	25	44	4.9	18.4	17.2	3.5	2.8	**At Risk**	**At Risk**	2.6	**0.7**	69.3	1.4	**0.7**	29
								Elkhorn River Basin											
ER-3	3	16.5	18.1	6.7	30	40	4.6	>50.0	>50.0	4.0	3.3	**At Risk**	**At Risk**	3.2	**0.9**	81.0	1.8	**0.9**	37
	SS	17.1	19.5	4.2	34	41	3.1	>50.0	>50.0	2.3	1.9	**At Risk**	**At Risk**	3.2	**0.8**	76.0	1.7	**0.9**	36
	SS	17.1	19.5	4.2	34	40	6.2	>50.0	>50.0	2.4	1.9	**At Risk**	**At Risk**	2.8	**0.4**	56.1	1.4	**0.6**	27
ER-4	2	16.4	17.9	10.8	28	42	2.6	>50.0	>50.0	6.4	5.1	Stable	Stable	4.8	2.4	--	3.0	2.1	***81***
	SS	16.3	17.8	17.0	25	36	2.3	>50.0	>50.0	11.9	10.0	Stable	Stable	8.0	5.2	--	4.8	3.7	***90***
	SS	16.3	17.8	17.0	25	39	2.5	>50.0	>50.0	10.8	8.9	Stable	Stable	6.9	4.4	--	4.3	3.3	***90***
	SS	16.3	17.8	17.0	25	30	2.5	>50.0	>50.0	14.1	12.2	Stable	Stable	9.0	5.7	--	4.6	3.6	***90***
	SS	16.3	17.8	17.0	25	45	2.9	45.5	42.2	9.3	7.4	Stable	Stable	5.4	3.3	--	3.3	2.4	***90***
	SS	16.3	17.8	17.0	25	55	2.4	22.6	19.3	7.3	5.4	Stable	Stable	4.8	3.0	--	3.8	2.8	***90***
	SS	16.3	17.8	17.0	25	44	3.1	46.9	43.6	9.4	7.5	Stable	Stable	5.2	3.0	--	3.0	2.1	***84***
ER-5	2	16.4	17.9	10.8	28	45	5.8	38.3	36.1	5.9	4.7	Stable	**At Risk**	3.0	1.0	--	1.7	**0.9**	41
	SS	13.8	17.2	19.4	28	64	5.2	23.4	18.6	7.2	4.9	Stable	**At Risk**	3.1	1.4	--	2.2	1.2	***70***
	SS	13.8	17.2	19.4	28	38	4.7	>50.0	>50.0	13.0	10.7	Stable	Stable	6.0	2.8	--	3.4	2.1	***75***
	SS	13.8	17.2	19.4	28	53	6.4	43.6	38.8	9.1	6.8	Stable	Stable	3.5	1.4	--	2.2	1.1	***59***
	SS	13.8	17.2	19.4	28	35	5.6	>50.0	>50.0	14.2	11.9	Stable	Stable	5.9	2.5	--	3.1	1.8	***66***
	SS	13.8	17.2	19.4	28	43	5.9	>50.0	>50.0	11.6	9.3	Stable	Stable	4.7	1.9	--	2.6	1.5	***62***
	SS	13.8	17.2	19.4	28	34	6.7	>50.0	>50.0	14.7	12.4	Stable	Stable	5.6	2.2	--	2.8	1.6	***58***
ER-6	4	16.5	18.1	6.7	30	41	2.4	>50.0	>50.0	3.9	3.2	Stable	Stable	4.0	1.6	--	2.5	1.6	***66***
	4*	16.5	18.1	6.7	30	33	2.8	>50.0	>50.0	5.0	4.3	Stable	Stable	4.8	1.8	--	2.5	1.5	***53***
	4*	16.5	18.1	6.7	30	44	1.7	32.7	31.3	3.6	2.9	Stable	Stable	4.4	2.1	--	3.0	2.0	***90***
	4*	16.5	18.1	6.7	30	31	3.4	>50.0	>50.0	5.3	4.6	Stable	Stable	4.7	1.6	--	2.3	1.3	***44***
	4*	16.5	18.1	6.7	30	54	1.6	13.4	11.9	2.9	2.2	Stable	Stable	3.6	1.8	--	2.8	1.8	***90***
	4*	16.5	18.1	6.7	30	38	3.5	>50.0	>50.0	4.3	3.5	Stable	Stable	3.7	1.2	--	2.1	1.1	***44***
	4*	16.5	18.1	6.7	30	47	1.6	24.9	23.4	3.4	2.7	Stable	Stable	4.2	2.1	--	3.0	2.0	***90***
	4*	16.5	18.1	6.7	30	38	3.3	>50.0	>50.0	4.3	3.5	Stable	Stable	3.8	1.3	--	2.1	1.2	***45***
	4*	16.5	18.1	6.7	30	44	1.5	36.8	35.4	3.7	3.0	Stable	Stable	4.8	2.4	--	3.2	2.2	***90***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Elkhorn River Basin--Continued											
ER-7	2	16.4	17.9	10.8	28	34	4.5	>50.0	>50.0	7.8	6.6	Stable	Stable	4.4	1.7	--	2.4	1.4	***52***
	SS	15.1	18.0	9.1	33	37	5.1	>50.0	>50.0	6.0	5.0	Stable	**At Risk**	4.1	1.2	--	2.3	1.2	***44***
	SS	15.1	18.0	9.1	33	32	4.0	>50.0	>50.0	7.1	6.1	Stable	Stable	5.4	1.8	--	2.8	1.6	***51***
ER-8	4	16.5	18.1	6.7	30	39	4.9	>50.0	>50.0	4.1	3.4	**At Risk**	**At Risk**	3.2	**0.8**	79.3	1.8	**0.9**	36
	4*	16.5	18.1	6.7	30	42	5.1	48.0	46.6	3.9	3.1	**At Risk**	**At Risk**	3.0	**0.8**	73.6	1.7	**0.8**	34
	4*	16.5	18.1	6.7	30	40	5.3	>50.0	>50.0	4.0	3.3	**At Risk**	**At Risk**	3.1	**0.8**	74.2	1.7	**0.8**	34
	4*	16.5	18.1	6.7	30	35	4.4	>50.0	>50.0	4.8	4.0	Stable	**At Risk**	3.8	1.1	--	2.0	1.1	***39***
	4*	16.5	18.1	6.7	30	44	5.1	34.6	33.1	3.7	2.9	**At Risk**	**At Risk**	2.8	**0.7**	71.5	1.6	**0.8**	35
	4*	16.5	18.1	6.7	30	39	4.5	>50.0	>50.0	4.1	3.4	**At Risk**	**At Risk**	3.3	**0.9**	85.4	1.8	**1.0**	38
	4*	16.5	18.1	6.7	30	36	4.9	>50.0	>50.0	4.5	3.8	**At Risk**	**At Risk**	3.5	**0.9**	86.4	1.9	**1.0**	36
ER-9	2	16.4	17.9	10.8	28	37	5.1	>50.0	>50.0	7.3	6.1	Stable	Stable	4.0	1.4	--	2.1	1.3	***47***
	SS	14.5	17.1	9.5	32	31	5.4	>50.0	>50.0	8.1	7.0	Stable	Stable	5.1	1.5	--	2.5	1.3	***42***
	SS	14.5	17.1	9.5	32	43	5.2	>50.0	>50.0	5.7	4.6	Stable	**At Risk**	3.6	1.1	--	2.1	**1.0**	***44***
	SS	14.5	17.1	9.5	32	31	5.3	>50.0	>50.0	7.9	6.8	Stable	Stable	5.0	1.5	--	2.5	1.3	***43***
	SS	14.5	17.1	9.5	32	38	4.4	>50.0	>50.0	6.5	5.4	Stable	Stable	4.4	1.5	--	2.5	1.3	***49***
	SS	14.5	17.1	9.5	32	32	5.1	>50.0	>50.0	7.7	6.6	Stable	Stable	4.9	1.5	--	2.5	1.3	***45***
	SS	14.5	17.1	9.5	32	43	4.6	>50.0	>50.0	5.6	4.5	Stable	**At Risk**	3.8	1.2	--	2.2	1.1	***48***
	SS	14.5	17.1	9.5	32	32	5.7	>50.0	>50.0	7.7	6.5	Stable	Stable	4.7	1.3	--	2.3	1.2	***40***
	SS	14.5	17.1	9.5	32	43	4.9	>50.0	>50.0	5.7	4.6	Stable	**At Risk**	3.7	1.1	--	2.1	1.1	***46***
ER-10	2	16.4	17.9	10.8	28	41	2.5	>50.0	>50.0	6.5	5.3	Stable	Stable	5.1	2.6	--	3.2	2.2	***87***
	SS	17.2	18.2	12.5	27	36	2.1	>50.0	>50.0	8.5	7.1	Stable	Stable	6.8	4.1	--	4.1	3.2	***90***
	SS	17.2	18.2	12.5	27	41	1.8	>50.0	>50.0	7.3	6.0	Stable	Stable	6.5	4.2	--	4.4	3.4	***90***
	SS	17.2	18.2	12.5	27	44	2.6	37.8	35.4	6.7	5.3	Stable	Stable	4.6	2.6	--	3.1	2.2	***89***
	SS	17.2	18.2	12.5	27	44	3.1	37.9	35.6	6.7	5.3	Stable	Stable	4.2	2.2	--	2.4	1.6	***70***
	SS	17.2	18.2	12.5	27	40	2.7	>50.0	>50.0	7.6	6.2	Stable	Stable	5.1	2.8	--	3.0	2.2	***83***
	SS	17.2	18.2	12.5	27	38	2.6	>50.0	>50.0	7.9	6.5	Stable	Stable	5.5	3.1	--	3.3	2.4	***89***
ER-11	2	16.4	17.9	10.8	28	24	0.6	>50.0	>50.0	11.3	10.1	Stable	Stable	23.2	17.7	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	17	0.6	>50.0	>50.0	20.3	18.7	Stable	Stable	42.4	35.0	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	19	0.8	>50.0	>50.0	18.4	16.9	Stable	Stable	30.8	24.6	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	15	0.6	>50.0	>50.0	23.0	21.4	Stable	Stable	45.9	37.7	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	26	0.5	>50.0	>50.0	13.6	12.0	Stable	Stable	33.9	28.6	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	32	0.5	>50.0	>50.0	10.9	9.4	Stable	Stable	26.1	22.0	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	31	0.4	>50.0	>50.0	11.4	9.8	Stable	Stable	33.9	29.2	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	26	0.8	>50.0	>50.0	13.7	12.1	Stable	Stable	21.4	16.9	--	bh	bh	bh
	SS	17.7	18.8	14.6	28	28	1.0	>50.0	>50.0	12.6	11.1	Stable	Stable	16.9	12.8	--	bh	bh	bh
ER-12	2	16.4	17.9	10.8	28	42	6.9	>50.0	48.7	6.3	5.1	**At Risk**	**At Risk**	3.0	**0.9**	83.8	1.7	**0.9**	37
	SS	18.7	19.1	10.3	27	30	7.1	>50.0	>50.0	8.0	6.9	Stable	**At Risk**	3.8	1.1	--	1.8	1.1	***34***
	SS	18.7	19.1	10.3	27	48	6.6	20.4	18.7	4.8	3.7	**At Risk**	**At Risk**	2.3	**0.7**	70.9	1.3	**0.7**	36
	SS	18.7	19.1	10.3	27	30	6.6	>50.0	>50.0	8.0	6.9	Stable	Stable	3.9	1.2	--	1.8	1.1	***36***
	SS	18.7	19.1	10.3	27	48	7.0	21.7	20.0	4.9	3.8	**At Risk**	**At Risk**	2.3	**0.7**	69.4	1.3	**0.7**	35
	SS	18.7	19.1	10.3	27	42	7.2	37.3	35.6	5.7	4.6	**At Risk**	**At Risk**	2.7	**0.8**	75.6	1.5	**0.8**	34
	SS	18.7	19.1	10.3	27	55	7.0	13.3	11.5	4.1	3.1	**At Risk**	**At Risk**	2.0	**0.6**	61.3	1.2	**0.6**	35

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Elkhorn River Basin--Continued											
ER-13	2	16.4	17.9	10.8	28	39	6.0	>50.0	>50.0	6.8	5.6	Stable	**At Risk**	3.5	1.1	--	1.8	**1.0**	***39***
	SS	15.0	17.8	23.4	29	42	7.3	>50.0	>50.0	13.7	11.1	Stable	Stable	4.5	1.9	--	2.7	1.6	***63***
	SS	15.0	17.8	23.4	29	31	5.4	>50.0	>50.0	19.0	16.3	Stable	Stable	7.3	3.5	--	3.6	2.3	***74***
	SS	15.0	17.8	23.4	29	44	5.5	>50.0	>50.0	13.1	10.4	Stable	Stable	5.0	2.4	--	3.0	1.9	***74***
	SS	15.0	17.8	23.4	29	34	5.4	>50.0	>50.0	17.3	14.7	Stable	Stable	6.7	3.2	--	3.5	2.3	***74***
	SS	15.0	17.8	23.4	29	50	6.8	>50.0	>50.0	11.2	8.6	Stable	Stable	3.8	1.6	--	2.4	1.4	***65***
	SS	15.0	17.8	23.4	29	33	5.4	>50.0	>50.0	17.7	15.1	Stable	Stable	6.8	3.3	--	3.5	2.3	***74***
ER-14	2	16.4	17.9	10.8	28	37	5.1	>50.0	>50.0	7.3	6.1	Stable	Stable	4.0	1.4	--	2.1	1.3	***47***
	SS	17.5	19.3	14.2	27	40	5.8	>50.0	>50.0	8.2	6.7	Stable	Stable	3.6	1.4	--	2.0	1.2	***49***
	SS	17.5	19.3	14.2	27	30	4.4	>50.0	>50.0	10.9	9.4	Stable	Stable	5.6	2.5	--	2.8	1.9	***63***
	SS	17.5	19.3	14.2	27	40	4.3	>50.0	>50.0	8.0	6.6	Stable	Stable	4.1	1.9	--	2.4	1.6	***64***
	SS	17.5	19.3	14.2	27	37	5.7	>50.0	>50.0	8.9	7.4	Stable	Stable	4.0	1.6	--	2.1	1.3	***50***
ER-15	2	16.4	17.9	10.8	28	40	4.9	>50.0	>50.0	6.6	5.4	Stable	Stable	3.6	1.3	--	2.1	1.2	***48***
	SS	17.0	18.6	16.7	11	34	5.5	26.7	24.4	11.8	10.0	Stable	Stable	4.0	2.2	--	1.7	1.3	***54***
	SS	17.0	18.6	16.7	11	46	4.8	15.1	12.8	8.5	6.7	Stable	Stable	3.1	1.8	--	1.7	1.3	***67***
	SS	17.0	18.6	16.7	11	36	4.6	23.9	21.5	11.1	9.3	Stable	Stable	4.2	2.4	--	2.0	1.5	***70***
	SS	17.0	18.6	16.7	11	45	5.1	15.7	13.3	8.7	6.9	Stable	Stable	3.0	1.7	--	1.6	1.2	***62***
	SS	17.0	18.6	16.7	11	26	4.7	45.8	43.4	15.3	13.5	Stable	Stable	5.6	3.2	--	2.1	1.7	***68***
	SS	17.0	18.6	16.7	11	40	5.2	19.0	16.7	9.8	8.0	Stable	Stable	3.4	1.9	--	1.7	1.3	***59***
	SS	17.0	18.6	16.7	11	38	4.6	21.0	18.7	10.4	8.6	Stable	Stable	3.9	2.2	--	1.9	1.5	***69***
	SS	17.0	18.6	16.7	11	57	4.8	10.6	8.2	6.7	4.9	Stable	Stable	2.4	1.4	--	1.5	1.1	***67***
ER-16	2	16.4	17.9	10.8	28	43	4.3	44.8	42.6	6.1	4.9	Stable	Stable	3.5	1.4	--	2.1	1.3	***53***
	SS	14.7	17.1	4.7	35	41	4.4	>50.0	>50.0	3.0	2.4	**At Risk**	**At Risk**	3.3	**0.7**	68.3	1.8	**0.8**	31
	SS	14.7	17.1	4.7	35	50	3.9	24.8	23.5	2.4	1.8	**At Risk**	**At Risk**	2.8	**0.6**	63.0	1.5	**0.6**	34
	SS	14.7	17.1	4.7	35	49	4.7	25.6	24.4	2.4	1.8	**At Risk**	**At Risk**	2.6	**0.5**	58.2	1.4	**0.5**	30
	SS	14.7	17.1	4.7	35	33	4.3	>50.0	>50.0	3.7	3.1	**At Risk**	**At Risk**	4.2	**0.8**	80.6	2.1	**1.0**	32
ER-17	2	16.4	17.9	10.8	28	37	4.6	>50.0	>50.0	7.2	6.0	Stable	Stable	4.1	1.6	--	2.3	1.4	***51***
	SS	15.2	18.1	11.0	28	33	4.9	>50.0	>50.0	8.2	7.0	Stable	Stable	4.8	1.7	--	2.4	1.4	***49***
	SS	15.2	18.1	11.0	28	44	4.4	46.6	44.2	6.0	4.8	Stable	Stable	3.7	1.4	--	2.2	1.2	***54***
	SS	15.2	18.1	11.0	28	36	4.7	>50.0	>50.0	7.4	6.2	Stable	Stable	4.4	1.6	--	2.4	1.4	***51***
	SS	15.2	18.1	11.0	28	36	4.4	>50.0	>50.0	7.5	6.3	Stable	Stable	4.6	1.7	--	2.5	1.5	***54***
	SS	15.2	18.1	11.0	28	43	4.6	>50.0	48.8	6.1	4.9	Stable	Stable	3.7	1.3	--	2.1	1.2	***52***
	SS	15.2	18.1	11.0	28	30	4.5	>50.0	>50.0	9.1	7.9	Stable	Stable	5.6	2.0	--	2.7	1.6	***53***
ER-18	2	16.4	17.9	10.8	28	40	3.9	>50.0	>50.0	6.6	5.4	Stable	Stable	4.0	1.7	--	2.3	1.4	***57***
	SS	16.3	17.3	3.2	31	41	3.7	28.0	27.3	2.0	1.6	**At Risk**	**At Risk**	2.8	**0.5**	61.0	1.4	**0.6**	27
	SS	16.3	17.3	3.2	31	44	3.8	17.6	16.9	1.8	1.5	**At Risk**	**At Risk**	2.5	**0.5**	57.7	1.3	**0.5**	27
	SS	16.3	17.3	3.2	31	34	3.5	>50.0	>50.0	2.4	2.0	**At Risk**	**At Risk**	3.4	**0.7**	69.4	1.7	**0.8**	27
	SS	16.3	17.3	3.2	31	34	3.7	>50.0	>50.0	2.4	2.1	**At Risk**	**At Risk**	3.4	**0.7**	68.6	1.7	**0.8**	27
	SS	16.3	17.3	3.2	31	38	4.4	>50.0	>50.0	2.2	1.8	**At Risk**	**At Risk**	2.9	**0.5**	59.8	1.5	**0.6**	26
	SS	16.3	17.3	3.2	31	48	4.3	11.0	10.3	1.7	1.3	**At Risk**	**At Risk**	2.2	**0.4**	52.1	1.1	**0.4**	26

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Elkhorn River Basin--Continued											
ER-19	2	16.4	17.9	10.8	28	38	4.7	>50.0	>50.0	7.0	5.8	Stable	Stable	3.9	1.5	--	2.2	1.3	***50***
	SS	14.5	17.6	5.0	30	34	4.0	>50.0	>50.0	3.7	3.1	**At Risk**	**At Risk**	3.9	**0.9**	87.1	1.9	**0.9**	32
	SS	14.5	17.6	5.0	30	42	4.9	40.7	39.5	3.0	2.4	**At Risk**	**At Risk**	3.0	**0.6**	64.9	1.6	**0.7**	29
	SS	14.5	17.6	5.0	30	29	5.0	>50.0	>50.0	4.3	3.8	**At Risk**	**At Risk**	4.4	**0.9**	84.0	2.0	**1.0**	29
	SS	14.5	17.6	5.0	30	47	5.1	19.7	18.5	2.6	2.0	**At Risk**	**At Risk**	2.6	**0.5**	59.2	1.3	**0.5**	28
ER-20	2	16.4	17.9	10.8	28	40	3.7	>50.0	>50.0	6.6	5.4	Stable	Stable	4.2	1.8	--	2.4	1.5	***59***
	SS	17.5	18.7	17.3	22	39	3.6	>50.0	48.0	10.4	8.5	Stable	Stable	4.9	2.8	--	2.7	2.0	***80***
	SS	17.5	18.7	17.3	22	44	3.5	34.1	31.2	9.1	7.3	Stable	Stable	4.4	2.6	--	2.6	1.9	***81***
	SS	17.5	18.7	17.3	22	36	3.8	>50.0	>50.0	11.3	9.4	Stable	Stable	5.2	3.0	--	2.8	2.0	***78***
	SS	17.5	18.7	17.3	22	24	3.4	>50.0	>50.0	17.3	15.4	Stable	Stable	8.7	5.1	--	3.5	2.7	***82***
	SS	17.5	18.7	17.3	22	49	3.5	24.7	21.8	8.1	6.2	Stable	Stable	3.9	2.3	--	2.5	1.8	***81***
	SS	17.5	18.7	17.3	22	47	4.1	28.0	25.1	8.5	6.6	Stable	Stable	3.8	2.1	--	2.3	1.7	***76***
ER-21	2	16.4	17.9	10.8	28	43	3.1	46.7	44.5	6.1	4.9	Stable	Stable	4.2	2.0	--	2.4	1.5	***64***
	2*	16.4	17.9	10.8	28	34	2.8	>50.0	>50.0	7.9	6.7	Stable	Stable	5.7	2.8	--	3.0	2.0	***71***
	2*	16.4	17.9	10.8	28	28	3.7	>50.0	>50.0	9.5	8.3	Stable	Stable	6.0	2.6	--	2.8	1.8	***59***
	2*	16.4	17.9	10.8	28	55	2.5	17.5	15.3	4.7	3.4	Stable	Stable	3.6	1.9	--	2.7	1.8	***87***
	2*	16.4	17.9	10.8	28	54	3.4	18.3	16.1	4.7	3.5	Stable	Stable	3.1	1.4	--	2.0	1.2	***61***
	2*	16.4	17.9	10.8	28	49	2.9	25.7	23.5	5.3	4.1	Stable	Stable	3.7	1.8	--	2.3	1.4	***67***
	2*	16.4	17.9	10.8	28	42	4.2	50.0	47.8	6.2	5.0	Stable	Stable	3.7	1.5	--	2.2	1.3	***54***
	2*	16.4	17.9	10.8	28	40	2.8	>50.0	>50.0	6.6	5.4	Stable	Stable	4.8	2.4	--	2.8	1.9	***74***
	2*	16.4	17.9	10.8	28	53	3.0	19.6	17.4	4.8	3.6	Stable	Stable	3.4	1.6	--	2.1	1.3	***64***
	2*	16.4	17.9	10.8	28	30	2.8	>50.0	>50.0	8.9	7.7	Stable	Stable	6.5	3.2	--	3.2	2.1	***72***
	2*	16.4	17.9	10.8	28	30	2.9	>50.0	>50.0	9.1	7.9	Stable	Stable	6.4	3.1	--	3.0	2.0	***68***
	2*	16.4	17.9	10.8	28	44	2.8	40.2	38.0	5.9	4.7	Stable	Stable	4.3	2.1	--	2.6	1.7	***71***
	2*	16.4	17.9	10.8	28	31	3.0	>50.0	>50.0	8.8	7.6	Stable	Stable	6.1	2.9	--	2.9	1.9	***64***
	2*	16.4	17.9	10.8	28	42	3.1	49.5	47.3	6.2	5.0	Stable	Stable	4.3	2.0	--	2.4	1.5	***64***
	2*	16.4	17.9	10.8	28	52	3.4	21.4	19.2	5.0	3.8	Stable	Stable	3.2	1.4	--	2.0	1.2	***61***
	2*	16.4	17.9	10.8	28	49	2.9	25.7	23.5	5.3	4.1	Stable	Stable	3.7	1.8	--	2.3	1.4	***67***
	2*	16.4	17.9	10.8	28	51	2.7	22.6	20.5	5.1	3.9	Stable	Stable	3.8	1.9	--	2.6	1.7	***78***
ER-22	2	16.4	17.9	10.8	28	37	1.8	>50.0	>50.0	7.3	6.1	Stable	Stable	6.8	4.0	--	4.2	3.1	***90***
	SS	17.5	17.9	17.3	20	47	1.7	24.5	21.7	8.8	6.9	Stable	Stable	6.8	5.2	--	5.0	4.3	***90***
	SS	17.5	17.9	17.3	20	43	2.0	31.3	28.4	9.7	7.8	Stable	Stable	6.7	5.0	--	4.7	4.0	***90***
	SS	17.5	17.9	17.3	20	22	1.4	>50.0	>50.0	19.8	17.9	Stable	Stable	17.7	14.0	--	6.8	5.9	***90***
	SS	17.5	17.9	17.3	20	42	2.4	34.0	31.2	10.0	8.1	Stable	Stable	5.9	4.2	--	3.9	3.2	***90***
	SS	17.5	17.9	17.3	20	32	1.4	>50.0	>50.0	13.4	11.4	Stable	Stable	11.8	9.3	--	6.1	5.3	***90***
	SS	17.5	17.9	17.3	20	33	2.1	>50.0	>50.0	13.1	11.2	Stable	Stable	8.6	6.3	--	4.8	4.1	***90***
ER-23	2	16.4	17.9	10.8	28	37	3.6	>50.0	>50.0	7.3	6.0	Stable	Stable	4.6	2.0	--	2.5	1.6	***60***
	SS	18.4	19.3	5.7	31	40	4.0	>50.0	>50.0	3.3	2.7	**At Risk**	**At Risk**	3.1	**0.8**	79.4	1.7	**0.9**	37
	SS	18.4	19.3	5.7	31	30	2.9	>50.0	>50.0	4.4	3.8	Stable	Stable	4.6	1.5	--	2.3	1.4	***45***
	SS	18.4	19.3	5.7	31	39	3.7	>50.0	>50.0	3.3	2.7	**At Risk**	**At Risk**	3.2	**0.9**	85.2	1.8	**1.0**	38
	SS	18.4	19.3	5.7	31	38	3.7	>50.0	>50.0	3.4	2.8	**At Risk**	**At Risk**	3.3	**0.9**	86.6	1.8	**1.0**	***38***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
									Elkhorn River Basin--Continued										
ER-24	2	16.4	17.9	10.8	28	39	4.3	>50.0	>50.0	6.8	5.5	Stable	Stable	3.9	1.6	--	2.2	1.4	***54***
	SS	16.9	18.3	11.0	27	31	4.5	>50.0	>50.0	8.6	7.4	Stable	Stable	4.9	1.9	--	2.4	1.5	***53***
	SS	16.9	18.3	11.0	27	48	4.1	26.6	24.5	5.4	4.2	Stable	Stable	3.2	1.3	--	1.9	1.2	***56***
	SS	16.9	18.3	11.0	27	37	4.2	>50.0	>50.0	7.3	6.1	Stable	Stable	4.2	1.7	--	2.3	1.5	***55***
	SS	16.9	18.3	11.0	27	42	4.4	48.3	46.2	6.3	5.1	Stable	Stable	3.6	1.4	--	2.1	1.3	***53***
ER-25	4	16.5	18.1	6.7	30	35	4.2	>50.0	>50.0	4.7	4.0	Stable	**At Risk**	3.9	1.1	--	2.1	1.1	***40***
	SS	16.3	18.8	6.7	30	22	3.9	>50.0	>50.0	7.2	6.5	Stable	Stable	6.4	1.8	--	2.9	1.7	***41***
	SS	16.3	18.8	6.7	30	49	3.7	20.0	18.5	3.1	2.4	**At Risk**	**At Risk**	2.8	**0.8**	79.4	1.6	**0.8**	42
	SS	16.3	18.8	6.7	30	34	4.2	>50.0	>50.0	4.6	3.9	Stable	**At Risk**	4.0	1.1	--	2.1	1.2	***40***
	SS	16.3	18.8	6.7	30	33	5.2	>50.0	>50.0	4.7	4.0	**At Risk**	**At Risk**	3.8	**0.9**	87.2	1.9	**1.0**	***34***
	SS	16.3	18.8	6.7	30	40	4.5	>50.0	>50.0	3.9	3.2	**At Risk**	**At Risk**	3.3	**0.9**	82.8	1.8	**1.0**	39
	SS	16.3	18.8	6.7	30	28	4.1	>50.0	>50.0	5.7	5.0	Stable	Stable	4.9	1.4	--	2.4	1.4	***41***
	SS	16.3	18.8	6.7	30	38	3.7	>50.0	>50.0	4.1	3.4	Stable	**At Risk**	3.7	1.1	--	2.0	1.1	***43***
	SS	16.3	18.8	6.7	30	34	4.1	>50.0	>50.0	4.6	3.9	Stable	**At Risk**	4.0	1.1	--	2.1	1.2	***41***
									Salt Creek Basin										
SC-1	2	16.4	17.9	10.8	28	43	3.0	47.5	45.3	6.2	5.0	Stable	Stable	4.3	2.1	--	2.5	1.6	***66***
	SS	16.8	18.1	7.8	26	47	2.6	18.5	17.0	4.0	3.1	Stable	Stable	3.4	1.5	--	2.2	1.4	***66***
	SS	16.8	18.1	7.8	26	39	2.9	40.8	39.3	4.9	4.0	Stable	Stable	4.0	1.7	--	2.2	1.4	***55***
	SS	16.8	18.1	7.8	26	25	2.9	>50.0	>50.0	7.6	6.8	Stable	Stable	6.1	2.6	--	2.7	1.8	***53***
	SS	16.8	18.1	7.8	26	50	3.1	15.0	13.5	3.7	2.9	Stable	**At Risk**	2.9	1.2	--	1.7	**1.0**	49
	SS	16.8	18.1	7.8	26	42	2.9	27.5	26.0	4.5	3.6	Stable	Stable	3.6	1.6	--	2.1	1.3	***56***
	SS	16.8	18.1	7.8	26	31	3.8	>50.0	>50.0	6.1	5.3	Stable	Stable	4.4	1.6	--	2.1	1.3	***45***
	SS	16.8	18.1	7.8	26	50	2.8	15.0	13.5	3.7	2.9	Stable	Stable	3.1	1.3	--	1.9	1.2	***60***
	SS	16.8	18.1	7.8	26	58	2.6	9.0	7.6	3.1	2.2	Stable	**At Risk**	2.6	1.2	--	1.8	1.1	***65***
SC-2	2	16.4	17.9	10.8	28	50	3.6	24.2	22.0	5.2	4.0	Stable	Stable	3.3	1.4	--	2.0	1.2	***59***
	SS	14.6	17.5	2.5	37	52	3.3	13.0	12.3	1.2	0.9	**At Risk**	**At Risk**	2.4	**0.4**	50.4	1.2	**0.3**	28
	SS	14.6	17.5	2.5	37	43	4.1	>50.0	>50.0	1.5	1.2	**At Risk**	**At Risk**	2.9	**0.4**	53.4	1.5	**0.5**	27
	SS	14.6	17.5	2.5	37	46	3.4	32.9	32.2	1.4	1.1	**At Risk**	**At Risk**	2.8	**0.4**	54.3	1.4	**0.4**	28
	SS	14.6	17.5	2.5	37	62	3.5	5.4	4.7	1.0	0.7	**At Risk**	**At Risk**	1.9	**0.3**	43.6	**1.0**	**0.2**	28
	SS	14.6	17.5	2.5	37	50	3.7	15.7	15.0	1.2	0.9	**At Risk**	**At Risk**	2.5	**0.3**	49.7	1.2	**0.3**	28
	SS	14.6	17.5	2.5	37	48	3.7	24.0	23.3	1.3	1.0	**At Risk**	**At Risk**	2.6	**0.4**	51.8	1.4	**0.4**	28
SC-3	2	16.4	17.9	10.8	28	37	5.0	>50.0	>50.0	7.1	5.9	Stable	Stable	3.9	1.4	--	2.1	1.3	***47***
	SS	15.7	17.5	8.5	33	31	5.3	>50.0	>50.0	7.0	6.0	Stable	Stable	4.7	1.3	--	2.4	1.3	***41***
	SS	15.7	17.5	8.5	33	47	4.7	46.3	44.3	4.5	3.5	**At Risk**	**At Risk**	3.1	**1.0**	89.5	1.9	**1.0**	45
	SS	15.7	17.5	8.5	33	38	5.0	>50.0	>50.0	5.6	4.7	Stable	**At Risk**	3.8	1.1	--	2.2	1.1	***43***
	SS	15.7	17.5	8.5	33	45	5.0	>50.0	>50.0	4.7	3.8	**At Risk**	**At Risk**	3.2	**0.9**	86.6	1.9	**0.9**	43
	SS	15.7	17.5	8.5	33	29	5.5	>50.0	>50.0	7.5	6.5	Stable	Stable	5.0	1.4	--	2.4	1.3	***40***
	SS	15.7	17.5	8.5	33	43	4.3	>50.0	>50.0	5.0	4.0	Stable	**At Risk**	3.6	1.1	--	2.1	1.1	***47***
	SS	15.7	17.5	8.5	33	35	5.0	>50.0	>50.0	6.2	5.2	Stable	Stable	4.2	1.2	--	2.3	1.2	***43***
	SS	15.7	17.5	8.5	33	33	5.5	>50.0	>50.0	6.6	5.7	Stable	Stable	4.4	1.2	--	2.3	1.2	***40***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which $F_S = 1$ for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
									Salt Creek Basin--Continued										
SC-4	2	16.4	17.9	10.8	28	32	2.7	>50.0	>50.0	8.3	7.1	Stable	Stable	6.1	3.1	--	3.2	2.2	***77***
	SS	15.6	18.2	2.7	34	14	1.9	>50.0	>50.0	4.7	4.5	Stable	Stable	10.3	2.4	--	ba	ba	ba
	SS	15.6	18.2	2.7	34	18	2.5	>50.0	>50.0	3.7	3.4	Stable	Stable	7.4	1.5	--	3.2	1.8	***34***
	SS	15.6	18.2	2.7	34	15	2.2	>50.0	>50.0	4.4	4.1	Stable	Stable	9.2	2.0	--	3.6	2.1	***38***
	SS	15.6	18.2	2.7	34	22	2.8	>50.0	>50.0	3.1	2.8	Stable	**At Risk**	6.1	1.1	--	2.8	1.5	***30***
	SS	15.6	18.2	2.7	34	16	1.9	>50.0	>50.0	4.2	3.9	Stable	Stable	9.1	2.2	--	3.6	2.2	***42***
	SS	15.6	18.2	2.7	34	20	2.6	>50.0	>50.0	3.3	3.0	Stable	Stable	6.6	1.3	--	3.0	1.6	***33***
	SS	15.6	18.2	2.7	34	15	1.9	>50.0	>50.0	4.5	4.2	Stable	Stable	9.8	2.3	--	3.7	2.2	***42***
	SS	15.6	18.2	2.7	34	18	2.7	>50.0	>50.0	3.8	3.5	Stable	Stable	7.5	1.4	--	3.1	1.7	***31***
	SS	15.6	18.2	2.7	34	59	2.4	5.4	4.8	1.1	0.8	**At Risk**	**At Risk**	2.1	**0.4**	53.2	1.3	**0.5**	36
	SS	15.6	18.2	2.7	34	41	2.8	>50.0	>50.0	1.6	1.3	**At Risk**	**At Risk**	3.1	**0.6**	63.8	1.6	**0.7**	30
	SS	15.6	18.2	2.7	34	44	3.4	29.3	28.6	1.5	1.2	**At Risk**	**At Risk**	2.7	**0.4**	56.9	1.4	**0.5**	28
	SS	15.6	18.2	2.7	34	45	3.4	23.8	23.2	1.4	1.1	**At Risk**	**At Risk**	2.7	**0.4**	56.1	1.4	**0.5**	28
	SS	15.6	18.2	2.7	34	45	3.6	22.2	21.6	1.4	1.1	**At Risk**	**At Risk**	2.6	**0.4**	54.6	1.4	**0.5**	28
	SS	15.6	18.2	2.7	34	82	3.8	1.7	1.1	0.7	0.4	**Unstable**	**Unstable**	1.2	**0.2**	19.5	**0.6**	**0.1**	28
SC-5	2	16.4	17.9	10.8	28	47	3.7	32.3	30.1	5.6	4.4	Stable	Stable	3.5	1.5	--	2.1	1.3	***59***
	SS	15.8	17.7	9.8	29	39	4.5	>50.0	>50.0	6.2	5.1	Stable	Stable	3.9	1.4	--	2.2	1.3	***49***
	SS	15.8	17.7	9.8	29	49	2.5	26.2	24.1	4.8	3.7	Stable	Stable	3.9	1.9	--	2.7	1.7	***79***
	SS	15.8	17.7	9.8	29	34	4.6	>50.0	>50.0	7.3	6.2	Stable	Stable	4.5	1.6	--	2.4	1.4	***48***
	SS	15.8	17.7	9.8	29	53	2.6	19.9	17.8	4.4	3.3	Stable	Stable	3.6	1.7	--	2.6	1.6	***79***
	SS	15.8	17.7	9.8	29	52	4.8	20.8	18.7	4.5	3.4	**At Risk**	**At Risk**	2.7	**0.9**	87.5	1.7	**0.9**	47
	SS	15.8	17.7	9.8	29	65	2.6	10.3	8.2	3.5	2.4	Stable	**At Risk**	2.8	1.3	--	2.2	1.3	***75***
	SS	15.8	17.7	9.8	29	35	5.1	>50.0	>50.0	7.1	6.0	Stable	Stable	4.2	1.4	--	2.2	1.3	***45***
	SS	15.8	17.7	9.8	29	45	2.8	37.0	34.9	5.3	4.2	Stable	Stable	4.1	1.9	--	2.6	1.6	***70***
SC-6	2	16.4	17.9	10.8	28	43	5.0	45.2	43.0	6.1	4.9	Stable	**At Risk**	3.3	1.2	--	1.9	1.1	***48***
	SS	14.6	18.0	5.0	33	36	5.2	>50.0	>50.0	3.4	2.9	**At Risk**	**At Risk**	3.6	**0.7**	69.4	1.8	**0.8**	29
	SS	14.6	18.0	5.0	33	50	4.7	19.1	17.9	2.4	1.8	**At Risk**	**At Risk**	2.5	**0.5**	58.7	1.4	**0.5**	31
	SS	14.6	18.0	5.0	33	30	4.8	>50.0	>50.0	4.2	3.6	**At Risk**	**At Risk**	4.5	**0.9**	82.5	2.1	**1.0**	***30***
	SS	14.6	18.0	5.0	33	56	5.1	11.6	10.3	2.1	1.5	**At Risk**	**At Risk**	2.2	**0.4**	52.3	1.2	**0.4**	30
SC-7	2	16.4	17.9	10.8	28	34	8.3	>50.0	>50.0	7.9	6.7	**At Risk**	**At Risk**	3.6	**1.0**	88.3	1.8	**1.0**	33
	SS	16.1	17.6	14.0	27	38	8.3	>50.0	>50.0	9.4	7.8	Stable	**At Risk**	3.5	1.1	--	1.9	**1.0**	***40***
	SS	16.1	17.6	14.0	27	28	8.4	>50.0	>50.0	12.7	11.1	Stable	Stable	4.7	1.5	--	2.2	1.3	***39***
	SS	16.1	17.6	14.0	27	32	8.4	>50.0	>50.0	11.2	9.6	Stable	Stable	4.1	1.3	--	2.0	1.2	***39***
	SS	16.1	17.6	14.0	27	28	8.4	>50.0	>50.0	12.9	11.3	Stable	Stable	4.8	1.5	--	2.2	1.3	***39***
	SS	16.1	17.6	14.0	27	33	8.7	>50.0	>50.0	10.9	9.3	Stable	Stable	4.0	1.2	--	2.0	1.1	***38***
	SS	16.1	17.6	14.0	27	45	7.8	43.3	40.4	7.7	6.1	**At Risk**	**At Risk**	2.9	**1.0**	95.3	1.7	**0.9**	41
SC-8	2	16.4	17.9	10.8	28	40	6.0	>50.0	>50.0	6.6	5.3	Stable	**At Risk**	3.3	1.1	--	1.8	**1.0**	39
	SS	16.6	18.3	12.0	31	40	6.1	>50.0	>50.0	7.1	5.8	Stable	**At Risk**	3.6	1.2	--	2.0	1.1	***44***
	SS	16.6	18.3	12.0	31	31	5.3	>50.0	>50.0	9.4	8.1	Stable	Stable	5.0	1.8	--	2.6	1.5	***49***
	SS	16.6	18.3	12.0	31	45	6.3	>50.0	>50.0	6.3	5.0	**At Risk**	**At Risk**	3.1	**1.0**	95.8	1.8	**0.9**	43
	SS	16.6	18.3	12.0	31	45	6.4	>50.0	>50.0	6.4	5.1	**At Risk**	**At Risk**	3.2	**1.0**	98.0	1.8	**1.0**	43

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which $F_S = 1$ for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
									Salt Creek Basin--Continued										
SC-9	2	16.4	17.9	10.8	28	35	3.2	>50.0	>50.0	7.7	6.5	Stable	Stable	5.2	2.4	--	2.7	1.7	***62***
	SS	18.2	19.0	13.0	27	29	3.4	>50.0	>50.0	10.4	9.0	Stable	Stable	6.0	3.0	--	2.9	2.0	***68***
	SS	18.2	19.0	13.0	27	42	3.9	45.9	43.6	7.1	5.7	Stable	Stable	3.8	1.8	--	2.3	1.5	***64***
	SS	18.2	19.0	13.0	27	31	3.4	>50.0	>50.0	10.0	8.6	Stable	Stable	5.8	2.9	--	2.8	2.0	***68***
	SS	18.2	19.0	13.0	27	35	2.6	>50.0	>50.0	8.7	7.3	Stable	Stable	5.9	3.4	--	3.4	2.5	***90***
	SS	18.2	19.0	13.0	27	36	3.2	>50.0	>50.0	8.3	6.9	Stable	Stable	5.0	2.6	--	2.7	1.9	***70***
	SS	18.2	19.0	13.0	27	36	2.8	>50.0	>50.0	8.5	7.1	Stable	Stable	5.5	3.0	--	3.1	2.2	***82***
SC-10	2	16.4	17.9	10.8	28	34	4.7	>50.0	>50.0	7.9	6.7	Stable	Stable	4.4	1.7	--	2.3	1.4	***50***
	SS	17.7	18.2	11.7	23	32	4.9	>50.0	>50.0	8.9	7.6	Stable	Stable	4.2	1.8	--	2.1	1.4	***49***
	SS	17.7	18.2	11.7	23	40	5.0	35.8	33.8	7.0	5.8	Stable	Stable	3.3	1.4	--	1.8	1.2	***48***
	SS	17.7	18.2	11.7	23	35	4.8	>50.0	>50.0	8.2	6.9	Stable	Stable	4.0	1.7	--	2.0	1.4	***51***
	SS	17.7	18.2	11.7	23	34	4.3	>50.0	>50.0	8.3	7.0	Stable	Stable	4.2	1.9	--	2.2	1.5	***55***
	SS	17.7	18.2	11.7	23	40	4.8	35.9	33.9	7.1	5.8	Stable	Stable	3.4	1.5	--	1.9	1.2	***51***
	SS	17.7	18.2	11.7	23	22	4.6	>50.0	>50.0	13.0	11.7	Stable	Stable	6.4	2.8	--	2.6	1.8	***52***
SC-11	2	16.4	17.9	10.8	28	33	7.9	>50.0	>50.0	8.0	6.8	Stable	**At Risk**	3.7	1.0	--	1.9	**1.0**	***34***
	SS	17.7	18.5	14.6	26	31	6.8	>50.0	>50.0	11.4	9.8	Stable	Stable	4.4	1.7	--	2.1	1.3	***45***
	SS	17.7	18.5	14.6	26	36	8.3	>50.0	>50.0	9.6	8.0	Stable	**At Risk**	3.4	1.2	--	1.8	1.1	***41***
	SS	17.7	18.5	14.6	26	39	7.8	>50.0	>50.0	8.9	7.4	Stable	**At Risk**	3.3	1.1	--	1.8	1.1	***42***
	SS	17.7	18.5	14.6	26	28	8.7	>50.0	>50.0	12.8	11.3	Stable	Stable	4.5	1.5	--	2.1	1.3	***39***
SC-12	2	16.4	17.9	10.8	28	47	4.7	30.6	28.4	5.5	4.3	Stable	**At Risk**	3.1	1.2	--	1.9	1.1	***50***
	SS	17.4	18.3	8.6	27	50	4.5	17.4	15.8	4.1	3.1	**At Risk**	**At Risk**	2.6	**0.9**	83.3	1.5	**0.9**	44
	SS	17.4	18.3	8.6	27	38	4.6	>50.0	>50.0	5.5	4.5	Stable	**At Risk**	3.4	1.2	--	1.9	1.1	***43***
	SS	17.4	18.3	8.6	27	53	5.4	14.1	12.5	3.8	2.9	**At Risk**	**At Risk**	2.2	**0.7**	67.7	1.3	**0.7**	38
	SS	17.4	18.3	8.6	27	48	4.5	19.4	17.8	4.2	3.3	**At Risk**	**At Risk**	2.6	**0.9**	85.1	1.6	**0.9**	44
SC-13	2	16.4	17.9	10.8	28	32	9.6	>50.0	>50.0	8.5	7.3	**At Risk**	**At Risk**	3.7	**0.9**	83.5	1.8	**0.9**	30
	SS	18.0	19.0	8.7	36	38	9.5	>50.0	>50.0	5.3	4.3	**At Risk**	**At Risk**	3.1	**0.6**	64.3	1.8	**0.8**	32
	SS	18.0	19.0	8.7	36	25	8.6	>50.0	>50.0	8.3	7.4	**At Risk**	**At Risk**	5.0	**1.0**	91.5	2.6	1.4	***34***
	SS	18.0	19.0	8.7	36	60	9.9	15.2	13.3	3.2	2.3	**At Risk**	**At Risk**	1.8	**0.3**	45.8	1.1	**0.3**	32
	SS	18.0	19.0	8.7	36	15	9.1	>50.0	>50.0	14.2	13.2	Stable	Stable	8.5	1.6	--	ba	ba	ba
	SS	18.0	19.0	8.7	36	25	5.9	>50.0	>50.0	8.1	7.2	Stable	Stable	5.4	1.4	--	2.7	1.6	***39***
	SS	18.0	19.0	8.7	36	22	10.2	>50.0	>50.0	9.4	8.4	**At Risk**	**At Risk**	5.5	**0.9**	88.4	2.7	1.5	***31***
	SS	18.0	19.0	8.7	36	29	10.7	>50.0	>50.0	7.2	6.3	**At Risk**	**At Risk**	4.2	**0.7**	73.1	2.1	1.1	***30***
	SS	18.0	19.0	8.7	36	35	9.4	>50.0	>50.0	5.9	4.9	**At Risk**	**At Risk**	3.5	**0.6**	68.2	1.9	**0.9**	33
	SS	18.0	19.0	8.7	36	34	10.0	>50.0	>50.0	6.0	5.1	**At Risk**	**At Risk**	3.5	**0.6**	67.7	1.9	**0.9**	31
	SS	18.0	19.0	8.7	36	29	10.8	>50.0	>50.0	7.0	6.1	**At Risk**	**At Risk**	4.0	**0.6**	71.4	2.1	**1.0**	***30***
	SS	18.0	19.0	8.7	36	32	9.9	>50.0	>50.0	6.3	5.4	**At Risk**	**At Risk**	3.7	**0.6**	68.7	2.0	**1.0**	32
	SS	18.0	19.0	8.7	36	37	11.1	>50.0	>50.0	5.4	4.5	**At Risk**	**At Risk**	3.1	**0.5**	61.2	1.7	**0.8**	30

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which $F_S = 1$ for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Salt Creek Basin--Continued																			
SC-14	1	15.9	17.6	13.6	26	43	3.9	49.0	46.2	7.9	6.3	Stable	Stable	4.2	2.0	--	2.5	1.6	***67***
	SS	16.3	18.4	15.1	37	41	3.5	>50.0	>50.0	8.8	7.1	Stable	Stable	5.5	2.5	--	3.4	2.1	***72***
	SS	16.3	18.4	15.1	37	45	4.3	>50.0	>50.0	8.0	6.4	Stable	Stable	4.5	1.9	--	2.9	1.7	***67***
SC-15	1	15.9	17.6	13.6	26	40	2.8	>50.0	>50.0	8.6	7.0	Stable	Stable	5.5	3.0	--	3.1	2.2	***82***
	1*	15.9	17.6	13.6	26	43	2.7	48.7	46.0	7.9	6.3	Stable	Stable	5.2	2.9	--	3.2	2.2	***86***
	1*	15.9	17.6	13.6	26	28	2.9	>50.0	>50.0	12.5	11.0	Stable	Stable	7.9	4.3	--	3.5	2.5	***79***
	1*	15.9	17.6	13.6	26	38	2.6	>50.0	>50.0	9.1	7.5	Stable	Stable	6.2	3.5	--	3.7	2.7	***90***
	1*	15.9	17.6	13.6	26	45	2.6	40.6	37.9	7.5	6.0	Stable	Stable	5.1	2.9	--	3.3	2.3	***90***
	1*	15.9	17.6	13.6	26	44	2.9	42.3	39.6	7.6	6.0	Stable	Stable	4.9	2.7	--	2.9	2.0	***81***
	1*	15.9	17.6	13.6	26	40	3.1	>50.0	>50.0	8.6	7.0	Stable	Stable	5.2	2.7	--	2.8	1.9	***74***
	1*	15.9	17.6	13.6	26	37	3.1	>50.0	>50.0	9.1	7.6	Stable	Stable	5.6	2.9	--	2.9	2.0	***74***
	1*	15.9	17.6	13.6	26	42	2.8	>50.0	49.8	8.0	6.5	Stable	Stable	5.2	2.9	--	3.1	2.2	***84***
SC-16	2	16.4	17.9	10.8	28	48	2.0	27.7	25.5	5.4	4.2	Stable	Stable	4.8	2.7	--	3.6	2.5	***90***
	SS	13.5	16.3	14.1	22	62	1.5	14.2	11.1	5.7	4.0	Stable	Stable	6.0	3.9	--	5.4	3.8	***90***
	SS	13.5	16.3	14.1	22	49	1.7	25.7	22.7	7.6	5.8	Stable	Stable	7.0	4.4	--	5.4	3.7	***90***
	SS	13.5	16.3	14.1	22	35	1.6	>50.0	>50.0	11.1	9.4	Stable	Stable	11.0	7.0	--	6.1	4.5	***90***
	SS	13.5	16.3	14.1	22	52	2.4	22.5	19.4	7.1	5.4	Stable	Stable	5.2	3.0	--	3.9	2.6	***90***
	SS	13.5	16.3	14.1	22	38	2.5	>50.0	>50.0	10.1	8.4	Stable	Stable	7.2	4.1	--	4.1	2.8	***90***
	SS	13.5	16.3	14.1	22	47	2.4	29.3	26.3	8.0	6.2	Stable	Stable	5.8	3.3	--	4.1	2.8	***90***
	SS	13.5	16.3	14.1	22	54	1.5	20.3	17.2	6.8	5.1	Stable	Stable	6.9	4.5	--	5.6	3.9	***90***
	SS	13.5	16.3	14.1	22	50	2.3	24.2	21.1	7.4	5.6	Stable	Stable	5.5	3.2	--	4.1	2.7	***90***
SC-17	1	15.9	17.6	13.6	26	48	2.0	30.6	27.9	6.9	5.3	Stable	Stable	5.7	3.5	--	4.3	3.2	***90***
	SS	17.2	18.0	13.8	27	45	1.8	40.6	38.0	7.5	5.9	Stable	Stable	6.3	4.2	--	4.5	3.6	***90***
	SS	17.2	18.0	13.8	27	52	2.1	23.5	20.9	6.3	4.8	Stable	Stable	4.7	2.9	--	3.7	2.8	***90***
SC-18	1	15.9	17.6	13.6	26	48	1.2	31.3	28.5	6.9	5.4	Stable	Stable	8.5	6.0	--	5.6	4.3	***90***
	SS	17.6	18.1	3.5	25	57	1.3	3.9	3.3	1.4	1.0	Stable	**At Risk**	2.5	1.1	--	1.7	1.1	***65***
	SS	17.6	18.1	3.5	25	40	1.3	12.5	11.9	2.1	1.7	Stable	Stable	3.7	1.7	--	2.1	1.4	***66***
	SS	17.6	18.1	3.5	25	54	0.9	4.5	3.8	1.5	1.1	Stable	Stable	3.1	1.6	--	bh	bh	bh
	SS	17.6	18.1	3.5	25	41	1.2	12.1	11.5	2.1	1.7	Stable	Stable	3.8	1.8	--	2.1	1.4	***69***
SC-19	1	15.9	17.6	13.6	26	38	2.7	>50.0	>50.0	9.1	7.6	Stable	Stable	6.1	3.4	--	3.5	2.5	***90***
	1*	15.9	17.6	13.6	26	45	2.8	39.8	37.1	7.5	5.9	Stable	Stable	4.8	2.6	--	3.0	2.0	***83***
	1*	15.9	17.6	13.6	26	41	2.6	>50.0	>50.0	8.4	6.8	Stable	Stable	5.7	3.3	--	3.6	2.5	***90***
	1*	15.9	17.6	13.6	26	27	2.9	>50.0	>50.0	12.7	11.1	Stable	Stable	8.1	4.4	--	3.6	2.5	***79***
	1*	15.9	17.6	13.6	26	27	2.7	>50.0	>50.0	12.8	11.3	Stable	Stable	8.6	4.8	--	4.0	2.9	***89***
	1*	15.9	17.6	13.6	26	35	2.6	>50.0	>50.0	9.9	8.4	Stable	Stable	6.7	3.8	--	3.7	2.7	***90***
	1*	15.9	17.6	13.6	26	52	2.4	24.0	21.2	6.3	4.8	Stable	Stable	4.5	2.6	--	3.3	2.4	***90***
	1*	15.9	17.6	13.6	26	36	2.7	>50.0	>50.0	9.5	7.9	Stable	Stable	6.3	3.5	--	3.5	2.4	***87***
	1*	15.9	17.6	13.6	26	37	2.4	>50.0	>50.0	9.1	7.6	Stable	Stable	6.5	3.7	--	3.9	2.8	***90***
SC-21	2	16.4	17.9	10.8	28	44	6.7	39.2	37.0	5.9	4.7	**At Risk**	**At Risk**	2.9	**0.9**	81.4	1.6	**0.8**	37
	2	16.4	17.9	10.8	28	48	7.1	28.7	26.5	5.4	4.2	**At Risk**	**At Risk**	2.6	**0.8**	72.8	1.5	**0.7**	36
	2	16.4	17.9	10.8	28	41	6.4	>50.0	>50.0	6.4	5.2	Stable	**At Risk**	3.2	1.0	--	1.7	**0.9**	38

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb} (kN/m^3)	Saturated soil unit weight, γ_{sat} (kN/m^3)	Effective cohesion, c' (kPa)	Friction angle, ϕ (°)	Vertically weighted bank angle (°)	Bank height (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Without tension cracks	With tension cracks	Ambient CW0--BW0 (F_S)	Saturated CW0--BW100 (F_S)	BWyy at which F_S = 1 for CW0 (%)	Ambient (F_S)	Saturated (F_S)	Maximum expected stable bank angle (saturated) (°)
Salt Creek Basin--Continued																			
SC-22	2	16.4	17.9	10.8	28	40	9.7	>50.0	>50.0	6.6	5.4	**At Risk**	**At Risk**	2.9	**0.7**	69.4	1.5	**0.8**	30
	SS	18.4	19.5	8.1	36	31	9.7	>50.0	>50.0	6.0	5.2	**At Risk**	**At Risk**	3.8	**0.6**	68.7	2.0	**1.0**	***32***
	SS	18.4	19.5	8.1	36	41	9.9	>50.0	>50.0	4.5	3.6	**At Risk**	**At Risk**	2.8	**0.5**	59.3	1.6	**0.7**	31
	SS	18.4	19.5	8.1	36	44	10.4	>50.0	>50.0	4.1	3.3	**At Risk**	**At Risk**	2.6	**0.4**	55.2	1.5	**0.6**	30
	SS	18.4	19.5	8.1	36	40	8.6	>50.0	>50.0	4.5	3.7	**At Risk**	**At Risk**	3.0	**0.5**	62.6	1.7	**0.8**	34
	SS	18.4	19.5	8.1	36	51	11.3	34.0	32.3	3.5	2.7	**At Risk**	**At Risk**	2.1	**0.3**	49.4	1.2	**0.4**	29
	SS	18.4	19.5	8.1	36	40	8.6	>50.0	>50.0	4.6	3.7	**At Risk**	**At Risk**	3.0	**0.5**	62.6	1.7	**0.8**	34
	SS	18.4	19.5	8.1	36	34	10.5	>50.0	>50.0	5.5	4.7	**At Risk**	**At Risk**	3.5	**0.5**	63.7	1.9	**0.9**	30
	SS	18.4	19.5	8.1	36	42	8.4	>50.0	>50.0	4.3	3.4	**At Risk**	**At Risk**	2.8	**0.5**	61.2	1.6	**0.8**	34
SC-23	2	16.4	17.9	10.8	28	39	4.9	>50.0	>50.0	6.8	5.6	Stable	Stable	3.7	1.4	--	2.1	1.2	***48***
	SS	18.2	18.9	11.6	32	38	5.6	>50.0	>50.0	7.1	5.9	Stable	Stable	3.7	1.3	--	2.1	1.2	***47***
	SS	18.2	18.9	11.6	32	42	4.7	>50.0	>50.0	6.4	5.1	Stable	Stable	3.6	1.4	--	2.2	1.3	***54***
	SS	18.2	18.9	11.6	32	37	4.8	>50.0	>50.0	7.2	6.0	Stable	Stable	4.0	1.5	--	2.3	1.4	***53***
	SS	18.2	18.9	11.6	32	37	4.8	>50.0	>50.0	7.4	6.2	Stable	Stable	4.1	1.6	--	2.4	1.5	***53***
	SS	18.2	18.9	11.6	32	47	5.0	44.6	42.3	5.6	4.4	Stable	**At Risk**	3.1	1.1	--	1.9	1.1	***51***
	SS	18.2	18.9	11.6	32	35	4.9	>50.0	>50.0	7.8	6.5	Stable	Stable	4.3	1.6	--	2.4	1.5	***52***
	SS	18.2	18.9	11.6	32	44	5.2	>50.0	>50.0	6.1	4.8	Stable	**At Risk**	3.3	1.2	--	2.0	1.2	***50***
	SS	18.2	18.9	11.6	32	36	4.4	>50.0	>50.0	7.6	6.4	Stable	Stable	4.4	1.7	--	2.5	1.6	***56***
	SS	18.2	18.9	11.6	32	34	5.2	>50.0	>50.0	7.9	6.7	Stable	Stable	4.3	1.5	--	2.3	1.4	***49***
	SS	18.2	18.9	11.6	32	36	4.6	>50.0	>50.0	7.5	6.2	Stable	Stable	4.2	1.6	--	2.4	1.5	***54***
	SS	18.2	18.9	11.6	32	46	5.1	>50.0	49.6	5.8	4.6	Stable	**At Risk**	3.1	1.1	--	1.9	1.1	***50***
	SS	18.2	18.9	11.6	32	35	5.0	>50.0	>50.0	7.7	6.5	Stable	Stable	4.2	1.5	--	2.4	1.5	***51***
SC-24	2	16.4	17.9	10.8	28	36	4.0	>50.0	>50.0	7.4	6.2	Stable	Stable	4.5	1.8	--	2.4	1.5	***56***
	SS	17.8	18.6	11.2	20	35	4.2	42.1	40.2	7.7	6.5	Stable	Stable	3.9	1.8	--	2.0	1.4	***53***
	SS	17.8	18.6	11.2	20	38	4.1	30.4	28.6	7.0	5.8	Stable	Stable	3.6	1.7	--	1.9	1.3	***55***
	SS	17.8	18.6	11.2	20	26	4.2	>50.0	>50.0	10.6	9.4	Stable	Stable	5.4	2.5	--	2.3	1.6	***53***
	SS	17.8	18.6	11.2	20	47	4.0	15.8	14.0	5.5	4.3	Stable	Stable	2.9	1.4	--	1.7	1.2	***56***
	SS	17.8	18.6	11.2	20	31	3.9	>50.0	>50.0	8.6	7.4	Stable	Stable	4.6	2.2	--	2.2	1.5	***57***
	SS	17.8	18.6	11.2	20	25	3.9	>50.0	>50.0	10.7	9.5	Stable	Stable	5.7	2.7	--	2.4	1.7	***56***
	SS	17.8	18.6	11.2	20	31	3.8	>50.0	>50.0	8.7	7.4	Stable	Stable	4.7	2.3	--	2.2	1.5	***57***
	SS	17.8	18.6	11.2	20	43	4.0	21.5	19.7	6.2	5.0	Stable	Stable	3.3	1.6	--	1.8	1.3	***56***
	SS	17.8	18.6	11.2	20	35	3.9	43.1	41.3	7.7	6.5	Stable	Stable	4.1	2.0	--	2.1	1.4	***56***
	SS	17.8	18.6	11.2	20	48	4.4	14.9	13.1	5.3	4.1	Stable	**At Risk**	2.7	1.2	--	1.6	1.1	***52***
SC-25	2	16.4	17.9	10.8	28	42	5.4	48.7	46.5	6.2	5.0	Stable	**At Risk**	3.3	1.1	--	1.9	**1.0**	***44***
	SS	18.7	19.2	4.6	27	53	5.2	6.8	6.0	1.9	1.4	**At Risk**	**At Risk**	1.8	**0.4**	48.9	**0.9**	**0.4**	26
	SS	18.7	19.2	4.6	27	39	5.9	25.1	24.3	2.7	2.2	**At Risk**	**At Risk**	2.5	**0.5**	59.1	1.2	**0.6**	25
	SS	18.7	19.2	4.6	27	41	5.5	18.2	17.4	2.5	2.1	**At Risk**	**At Risk**	2.3	**0.5**	58.4	1.2	**0.6**	25
	SS	18.7	19.2	4.6	27	37	5.2	34.2	33.4	2.9	2.4	**At Risk**	**At Risk**	2.7	**0.6**	64.3	1.3	**0.7**	26

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb} (kN/m^3)	Saturated soil unit weight, γ_{sat} (kN/m^3)	Effective cohesion, c' (kPa)	Friction angle, ϕ (°)	Vertically weighted bank angle (°)	Bank height (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Without tension cracks	With tension cracks	Ambient CW0--BW0 (F_S)	Saturated CW0--BW100 (F_S)	BWyy at which F_S = 1 for CW0 (%)	Ambient (F_S)	Saturated (F_S)	Maximum expected stable bank angle (saturated) (°)
									Salt Creek Basin--Continued										
SC-26	2	16.4	17.9	10.8	28	43	7.5	46.0	43.8	6.1	4.9	**At Risk**	**At Risk**	2.9	**0.8**	76.3	1.6	**0.8**	35
	SS	15.6	18.3	8.5	37	42	6.1	>50.0	>50.0	4.9	3.9	**At Risk**	**At Risk**	3.5	**0.8**	76.8	2.0	**0.9**	39
	SS	15.6	18.3	8.5	37	44	8.5	>50.0	>50.0	4.5	3.6	**At Risk**	**At Risk**	3.0	**0.5**	62.1	1.7	**0.7**	34
	SS	15.6	18.3	8.5	37	45	6.9	>50.0	>50.0	4.5	3.6	**At Risk**	**At Risk**	3.1	**0.7**	67.5	1.8	**0.8**	37
	SS	15.6	18.3	8.5	37	49	7.8	>50.0	>50.0	4.0	3.1	**At Risk**	**At Risk**	2.7	**0.5**	59.9	1.5	**0.6**	36
	SS	15.6	18.3	8.5	37	46	6.3	>50.0	>50.0	4.4	3.5	**At Risk**	**At Risk**	3.1	**0.7**	70.0	1.8	**0.8**	38
	SS	15.6	18.3	8.5	37	32	9.6	>50.0	>50.0	6.5	5.6	**At Risk**	**At Risk**	4.2	**0.7**	71.7	2.2	**1.0**	***32***
SC-27	2	16.4	17.9	10.8	28	41	6.1	>50.0	>50.0	6.5	5.3	Stable	**At Risk**	3.3	1.1	--	1.8	**1.0**	39
	SS	16.5	18.4	15.7	22	44	7.8	34.0	31.2	8.5	6.8	Stable	**At Risk**	2.9	1.1	--	1.6	**1.0**	42
	SS	16.5	18.4	15.7	22	45	7.8	31.0	28.2	8.2	6.5	Stable	**At Risk**	2.8	1.1	--	1.6	**1.0**	42
	SS	16.5	18.4	15.7	22	39	4.3	>50.0	47.3	9.6	7.9	Stable	Stable	4.5	2.3	--	2.5	1.7	***70***
	SS	16.5	18.4	15.7	22	38	5.6	>50.0	>50.0	9.9	8.2	Stable	Stable	3.9	1.8	--	2.0	1.3	***54***
	SS	16.5	18.4	15.7	22	44	5.8	32.0	29.2	8.3	6.6	Stable	Stable	3.3	1.4	--	1.8	1.1	***51***
	SS	16.5	18.4	15.7	22	33	5.5	>50.0	>50.0	11.4	9.7	Stable	Stable	4.6	2.1	--	2.2	1.5	***55***
SC-28	2	16.4	17.9	10.8	28	36	5.0	>50.0	>50.0	7.4	6.2	Stable	Stable	4.1	1.5	--	2.2	1.3	***48***
	SS	16.2	17.5	12.6	23	33	5.2	>50.0	>50.0	9.7	8.2	Stable	Stable	4.4	1.9	--	2.1	1.4	***50***
	SS	16.2	17.5	12.6	23	31	4.8	>50.0	>50.0	10.3	8.8	Stable	Stable	4.9	2.2	--	2.3	1.5	***55***
	SS	16.2	17.5	12.6	23	31	4.9	>50.0	>50.0	10.5	9.1	Stable	Stable	4.9	2.2	--	2.3	1.5	***54***
	SS	16.2	17.5	12.6	23	40	4.8	44.2	41.8	8.0	6.6	Stable	Stable	3.8	1.7	--	2.1	1.3	***55***
	SS	16.2	17.5	12.6	23	53	5.4	17.0	14.7	5.8	4.3	Stable	**At Risk**	2.6	1.1	--	1.5	**0.9**	48
	SS	16.2	17.5	12.6	23	29	4.8	>50.0	>50.0	11.3	9.8	Stable	Stable	5.3	2.3	--	2.4	1.6	***54***
SC-29	1	15.9	17.6	13.6	26	43	4.3	49.5	46.8	7.9	6.4	Stable	Stable	4.0	1.8	--	2.4	1.5	***63***
	SS	15.2	17.2	20.4	19	38	4.8	>50.0	>50.0	13.8	11.5	Stable	Stable	5.2	2.9	--	2.8	2.0	***78***
	SS	15.2	17.2	20.4	19	41	3.3	47.4	43.6	12.8	10.4	Stable	Stable	6.2	3.9	--	3.4	2.5	***90***
	SS	15.2	17.2	20.4	19	45	4.6	36.8	33.0	11.6	9.2	Stable	Stable	4.5	2.5	--	2.6	1.9	***80***
	SS	15.2	17.2	20.4	19	36	4.5	>50.0	>50.0	14.7	12.3	Stable	Stable	5.7	3.2	--	3.0	2.1	***81***
	SS	15.2	17.2	20.4	19	37	4.4	>50.0	>50.0	14.3	11.9	Stable	Stable	5.7	3.3	--	3.0	2.2	***83***
	SS	15.2	17.2	20.4	19	60	4.3	18.2	14.4	8.2	5.9	Stable	Stable	3.3	1.9	--	2.3	1.6	***83***
SC-30	2	16.4	17.9	10.8	28	48	5.7	28.6	26.4	5.4	4.2	**At Risk**	**At Risk**	2.8	**1.0**	89.6	1.6	**0.9**	42
	SS	12.6	16.7	9.4	34	52	6.0	39.2	36.4	4.6	3.5	**At Risk**	**At Risk**	3.1	**0.8**	73.7	1.7	**0.6**	38
	SS	12.6	16.7	9.4	34	44	5.3	>50.0	>50.0	5.6	4.5	Stable	**At Risk**	3.9	1.1		2.2	**1.0**	43
SC-31	3	16.5	18.1	6.7	30	31	1.5	>50.0	>50.0	5.4	4.6	Stable	Stable	6.9	3.5	--	3.7	2.6	***90***
	SS	16.7	17.6	3.1	28	15	0.9	>50.0	>50.0	5.4	5.0	Stable	Stable	12.5	6.1	--	bh	bh	bh
	SS	16.7	17.6	3.1	28	16	0.8	>50.0	>50.0	5.1	4.8	Stable	Stable	12.4	6.2	--	bh	bh	bh
	SS	16.7	17.6	3.1	28	31	0.7	>50.0	>50.0	2.5	2.2	Stable	Stable	6.6	3.5	--	bh	bh	bh
	SS	16.7	17.6	3.1	28	23	0.6	>50.0	>50.0	3.4	3.1	Stable	Stable	10.5	6.2	--	bh	bh	bh
	SS	16.7	17.6	3.1	28	32	0.9	>50.0	>50.0	2.5	2.1	Stable	Stable	5.6	2.7	--	bh	bh	bh
	SS	16.7	17.6	3.1	28	26	0.9	>50.0	>50.0	3.0	2.7	Stable	Stable	7.1	3.5	--	bh	bh	bh
	SS	16.7	17.6	3.1	28	25	1.0	>50.0	>50.0	3.2	2.8	Stable	Stable	6.8	3.1	--	2.9	1.9	***66***
	SS	16.7	17.6	3.1	28	29	1.2	>50.0	>50.0	2.7	2.3	Stable	Stable	5.3	2.2	--	2.5	1.6	***60***
	SS	16.7	17.6	3.1	28	44	3.8	11.2	10.6	1.7	1.4	**At Risk**	**At Risk**	2.3	**0.5**	56.4	1.2	**0.5**	25
	SS	16.7	17.6	3.1	28	67	4.6	2.7	2.1	1.1	0.7	**Unstable**	**Unstable**	1.4	**0.2**	31.0	**0.7**	**0.2**	23

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which $F_S = 1$ for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Salt Creek Basin--Continued											
SC-32	3	16.5	18.1	6.7	30	46	7.8	28.3	26.9	3.5	2.8	**At Risk**	**At Risk**	2.4	**0.4**	56.4	1.3	**0.5**	28
	SS	18.3	19.5	6.5	31	48	8.4	20.4	19.1	3.0	2.3	**At Risk**	**At Risk**	2.1	**0.4**	52.1	1.2	**0.5**	28
	SS	18.3	19.5	6.5	31	31	7.7	>50.0	>50.0	4.7	4.1	**At Risk**	**At Risk**	3.4	**0.6**	69.4	1.7	**0.9**	29
	SS	18.3	19.5	6.5	31	39	7.4	>50.0	>50.0	3.8	3.1	**At Risk**	**At Risk**	2.7	**0.5**	62.2	1.5	**0.7**	29
	SS	18.3	19.5	6.5	31	52	7.5	13.6	12.3	2.7	2.0	**At Risk**	**At Risk**	1.9	**0.4**	50.8	1.1	**0.4**	29
	SS	18.3	19.5	6.5	31	50	8.5	16.0	14.8	2.8	2.2	**At Risk**	**At Risk**	2.0	**0.3**	50.1	1.1	**0.4**	28
	SS	18.3	19.5	6.5	31	53	7.5	12.5	11.3	2.6	2.0	**At Risk**	**At Risk**	1.9	**0.4**	49.6	1.1	**0.4**	29
SC-33	2	16.4	17.9	10.8	28	36	5.1	>50.0	>50.0	7.5	6.3	Stable	Stable	4.0	1.5	--	2.2	1.3	***47***
	SS	17.2	18.3	2.3	36	32	4.6	>50.0	>50.0	1.8	1.5	**At Risk**	**At Risk**	3.6	**0.4**	58.5	1.8	**0.7**	26
	SS	17.2	18.3	2.3	36	35	5.2	>50.0	>50.0	1.6	1.3	**At Risk**	**At Risk**	3.2	**0.3**	53.4	1.6	**0.6**	26
	SS	17.2	18.3	2.3	36	38	4.9	>50.0	>50.0	1.4	1.2	**At Risk**	**At Risk**	2.9	**0.3**	51.8	1.5	**0.6**	26
	SS	17.2	18.3	2.3	36	32	5.3	>50.0	>50.0	1.8	1.5	**At Risk**	**At Risk**	3.5	**0.3**	55.5	1.7	**0.7**	26
	SS	17.2	18.3	2.3	36	37	5.1	>50.0	>50.0	1.5	1.3	**At Risk**	**At Risk**	3.0	**0.3**	53.2	1.5	**0.6**	26
	SS	17.2	18.3	2.3	36	41	5.5	>50.0	>50.0	1.4	1.1	**At Risk**	**At Risk**	2.7	**0.2**	49.5	1.4	**0.5**	25
	SS	17.2	18.3	2.3	36	35	5.0	>50.0	>50.0	1.6	1.3	**At Risk**	**At Risk**	3.1	**0.3**	53.8	1.6	**0.6**	26
	SS	17.2	18.3	2.3	36	39	5.5	>50.0	>50.0	1.4	1.2	**At Risk**	**At Risk**	2.8	**0.3**	50.0	1.4	**0.5**	25
	SS	17.2	18.3	2.3	36	35	4.6	>50.0	>50.0	1.6	1.3	**At Risk**	**At Risk**	3.2	**0.3**	54.6	1.6	**0.6**	26
	SS	17.2	18.3	2.3	36	33	5.5	>50.0	>50.0	1.7	1.4	**At Risk**	**At Risk**	3.3	**0.3**	54.7	1.6	**0.6**	25
SC-34	2	16.4	17.9	10.8	28	32	2.4	>50.0	>50.0	8.5	7.3	Stable	Stable	6.7	3.5	--	3.6	2.6	***88***
	SS	17.7	18.4	7.4	33	25	3.1	>50.0	>50.0	7.2	6.4	Stable	Stable	6.3	2.3	--	3.0	1.9	***50***
	SS	17.7	18.4	7.4	33	38	1.4	>50.0	>50.0	4.6	3.8	Stable	Stable	6.1	3.4	--	3.8	2.7	***90***
	SS	17.7	18.4	7.4	33	23	2.8	>50.0	>50.0	7.8	7.0	Stable	Stable	7.2	2.8	--	3.4	2.2	***58***
	SS	17.7	18.4	7.4	33	40	1.9	>50.0	>50.0	4.5	3.7	Stable	Stable	4.9	2.3	--	3.3	2.2	***89***
	SS	17.7	18.4	7.4	33	33	2.7	>50.0	>50.0	5.4	4.6	Stable	Stable	5.1	2.0	--	2.8	1.8	***61***
	SS	17.7	18.4	7.4	33	30	2.7	>50.0	>50.0	6.0	5.2	Stable	Stable	5.6	2.2	--	3.0	1.9	***62***
								Little Nemaha River Basin											
LNR-1	2	16.4	17.9	10.8	28	40	4.9	>50.0	>50.0	6.7	5.5	Stable	Stable	3.7	1.4	--	2.1	1.2	***49***
	SS	18.6	19.3	16.6	21	43	4.6	31.0	28.4	8.7	7.0	Stable	Stable	3.6	1.9	--	2.1	1.5	***68***
	SS	18.6	19.3	16.6	21	36	5.3	>50.0	>50.0	10.7	9.0	Stable	Stable	4.1	2.0	--	2.1	1.5	***60***
	SS	18.6	19.3	16.6	21	50	4.8	20.9	18.3	7.5	5.7	Stable	Stable	3.0	1.6	--	1.9	1.3	***67***
	SS	18.6	19.3	16.6	21	31	4.8	>50.0	>50.0	12.4	10.7	Stable	Stable	5.0	2.6	--	2.4	1.8	***66***
LNR-2	2	16.4	17.9	10.8	28	36	4.4	>50.0	>50.0	7.4	6.2	Stable	Stable	4.3	1.7	--	2.3	1.4	***53***
	SS	16.2	18.2	19.4	26	32	5.3	>50.0	>50.0	14.8	12.7	Stable	Stable	5.8	2.8	--	2.9	1.9	***69***
	SS	16.2	18.2	19.4	26	30	3.8	>50.0	>50.0	15.9	13.8	Stable	Stable	7.7	4.2	--	3.7	2.6	***83***
	SS	16.2	18.2	19.4	26	48	4.8	42.1	38.2	9.5	7.3	Stable	Stable	3.9	2.0	--	2.5	1.6	***74***
	SS	16.2	18.2	19.4	26	35	3.8	>50.0	>50.0	13.6	11.5	Stable	Stable	6.5	3.6	--	3.4	2.4	***82***
	SS	16.2	18.2	19.4	26	40	4.6	>50.0	>50.0	11.8	9.7	Stable	Stable	5.1	2.6	--	2.9	2.0	***76***
	SS	16.2	18.2	19.4	26	33	4.0	>50.0	>50.0	14.4	12.2	Stable	Stable	6.6	3.6	--	3.4	2.4	***80***
LNR-3	2	16.4	17.9	10.8	28	38	4.7	>50.0	>50.0	7.0	5.8	Stable	Stable	4.0	1.5	--	2.2	1.3	***50***
	SS	18.0	18.7	7.9	32	33	5.5	>50.0	>50.0	5.7	4.9	Stable	**At Risk**	3.8	1.0	--	2.0	1.1	***37***
	SS	18.0	18.7	7.9	32	43	4.4	>50.0	>50.0	4.3	3.5	**At Risk**	**At Risk**	3.1	**1.0**	93.3	1.9	**1.0**	***44***
	SS	18.0	18.7	7.9	32	39	4.8	>50.0	>50.0	4.7	3.9	**At Risk**	**At Risk**	3.3	**1.0**	94.4	1.9	1.1	***42***
	SS	18.0	18.7	7.9	32	36	4.0	>50.0	>50.0	5.1	4.3	Stable	Stable	3.8	1.3	--	2.2	1.3	***47***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Little Nemaha River Basin--Continued											
LNR-4	2	16.4	17.9	10.8	28	37	5.2	>50.0	>50.0	7.2	5.9	Stable	Stable	3.8	1.4	--	2.1	1.2	***46***
	2*	16.4	17.9	15.1	34	39	5.5	>50.0	>50.0	9.6	7.9	Stable	Stable	4.5	1.8	--	2.6	1.5	***57***
	2*	16.4	17.9	15.1	34	38	4.6	>50.0	>50.0	9.7	8.0	Stable	Stable	4.9	2.1	--	2.9	1.8	***64***
	2*	16.4	17.9	15.1	34	33	5.8	>50.0	>50.0	11.4	9.7	Stable	Stable	5.2	2.0	--	2.8	1.6	***54***
	2*	16.4	17.9	15.1	34	41	4.5	>50.0	>50.0	9.1	7.4	Stable	Stable	4.7	2.0	--	2.9	1.8	***66***
	2*	16.4	17.9	15.1	34	37	5.6	>50.0	>50.0	10.1	8.4	Stable	Stable	4.7	1.8	--	2.7	1.6	***56***
	2*	16.4	17.9	15.1	34	36	5.4	>50.0	>50.0	10.4	8.7	Stable	Stable	4.9	1.9	--	2.8	1.6	***57***
LNR-5	2	16.4	17.9	10.8	28	40	10.2	>50.0	>50.0	6.6	5.4	**At Risk**	**At Risk**	2.8	**0.6**	67.1	1.5	**0.7**	29
	2*	16.4	17.9	12.8	23	42	10.8	36.4	34.0	7.5	6.1	**At Risk**	**At Risk**	2.6	**0.7**	69.4	1.3	**0.7**	27
	2*	16.4	17.9	12.8	23	45	9.5	27.2	24.8	6.8	5.4	**At Risk**	**At Risk**	2.4	**0.7**	70.2	1.3	**0.7**	30
	2*	16.4	17.9	12.8	23	33	10.8	>50.0	>50.0	9.6	8.2	**At Risk**	**At Risk**	3.3	**0.9**	83.1	1.5	**0.8**	27
	2*	16.4	17.9	12.8	23	41	9.6	38.0	35.7	7.6	6.2	**At Risk**	**At Risk**	2.7	**0.8**	75.4	1.4	**0.8**	30
LNR-6	2	16.4	17.9	10.8	28	53	8.9	19.6	17.4	4.8	3.6	**At Risk**	**At Risk**	2.1	**0.5**	58.9	1.2	**0.5**	32
	2*	16.4	17.9	12.7	29	51	8.9	28.7	26.1	5.9	4.5	**At Risk**	**At Risk**	2.4	**0.7**	65.7	1.4	**0.7**	37
	2*	16.4	17.9	12.7	29	36	9.6	>50.0	>50.0	8.7	7.3	**At Risk**	**At Risk**	3.4	**0.9**	84.6	1.8	**1.0**	35
	2*	16.4	17.9	12.7	29	57	8.5	19.2	16.5	5.2	3.8	**At Risk**	**At Risk**	2.1	**0.6**	61.6	1.3	**0.6**	38
	2*	16.4	17.9	12.7	29	61	8.6	16.0	13.3	4.8	3.4	**At Risk**	**At Risk**	2.0	**0.6**	57.9	1.2	**0.5**	38
	2*	16.4	17.9	12.7	29	70	8.9	10.3	7.7	4.0	2.6	**At Risk**	**Unstable**	1.6	**0.5**	46.8	**1.0**	**0.3**	37
	2*	16.4	17.9	12.7	29	43	8.7	>50.0	>50.0	7.3	5.9	**At Risk**	**At Risk**	3.0	**0.8**	78.1	1.7	**0.9**	37
LNR-7	2	16.4	17.9	10.8	28	45	4.2	36.7	34.5	5.8	4.6	Stable	Stable	3.4	1.4	--	2.1	1.2	***55***
	SS	17.4	18.5	8.8	23	52	4.8	11.6	10.1	3.9	3.0	**At Risk**	**At Risk**	2.3	**0.8**	76.3	1.3	**0.8**	40
	SS	17.4	18.5	8.8	23	39	3.9	28.1	26.6	5.3	4.4	Stable	Stable	3.3	1.4	--	1.8	1.2	***46***
	SS	17.4	18.5	8.8	23	28	3.4	>50.0	>50.0	7.7	6.8	Stable	Stable	5.2	2.3	--	2.3	1.5	***50***
	SS	17.4	18.5	8.8	23	65	5.2	6.5	5.0	3.0	2.0	**At Risk**	**Unstable**	1.7	**0.6**	55.5	**1.0**	**0.5**	37
	SS	17.4	18.5	8.8	23	48	3.0	14.0	12.5	4.2	3.3	Stable	Stable	3.0	1.4	--	1.7	1.1	***53***
	SS	17.4	18.5	8.8	23	39	4.7	28.0	26.5	5.3	4.4	Stable	**At Risk**	3.1	1.1	--	1.7	**1.0**	***41***
LNR-8	2	16.4	17.9	10.8	28	52	9.7	20.4	18.2	4.9	3.7	**At Risk**	**At Risk**	2.1	**0.5**	57.0	1.2	**0.5**	30
	SS	15.8	18.8	6.5	34	58	9.3	13.0	11.4	2.5	1.8	**At Risk**	**At Risk**	1.9	**0.3**	44.5	**1.0**	**0.3**	28
	SS	15.8	18.8	6.5	34	40	9.2	>50.0	>50.0	3.8	3.1	**At Risk**	**At Risk**	2.9	**0.4**	57.8	1.5	**0.6**	28
	SS	15.8	18.8	6.5	34	62	10.4	9.7	8.2	2.3	1.6	**Unstable**	**Unstable**	1.7	**0.2**	39.0	**0.9**	**0.2**	27
	SS	15.8	18.8	6.5	34	49	10.1	26.9	25.4	3.0	2.3	**At Risk**	**At Risk**	2.2	**0.3**	49.1	1.2	**0.4**	28
LNR-9	1	15.9	17.6	13.6	26	39	4.2	>50.0	>50.0	8.7	7.2	Stable	Stable	4.5	2.1	--	2.5	1.6	***64***
	SS	18.5	19.3	13.3	27	44	4.2	38.5	36.2	6.8	5.4	Stable	Stable	3.5	1.6	--	2.1	1.4	***62***
	SS	18.5	19.3	13.3	27	39	4.0	>50.0	>50.0	7.7	6.4	Stable	Stable	4.1	1.9	--	2.3	1.6	***64***
	SS	18.5	19.3	13.3	27	38	4.3	>50.0	>50.0	7.9	6.6	Stable	Stable	4.1	1.9	--	2.3	1.6	***62***
	SS	18.5	19.3	13.3	27	34	4.4	>50.0	>50.0	8.9	7.5	Stable	Stable	4.5	2.0	--	2.4	1.6	***60***
LNR-10	1	15.9	17.6	13.6	26	31	2.9	>50.0	>50.0	11.1	9.6	Stable	Stable	7.1	3.8	--	3.4	2.3	***79***
	SS	16.4	18.0	36.5	15	27	2.9	>50.0	>50.0	33.3	29.2	Stable	Stable	14.9	11.4	--	c	c	c
	SS	16.4	18.0	36.5	15	35	2.9	>50.0	>50.0	25.7	21.7	Stable	Stable	11.7	8.9	--	c	c	c

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
Little Nemaha River Basin--Continued																			
LNR-11	2	16.4	17.9	10.8	28	48	7.4	27.9	25.7	5.4	4.2	**At Risk**	**At Risk**	2.5	**0.7**	70.5	1.4	**0.7**	36
	2*	16.4	17.9	10.8	28	47	7.2	30.5	28.3	5.5	4.3	**At Risk**	**At Risk**	2.6	**0.8**	72.6	1.5	**0.7**	36
	2*	16.4	17.9	10.8	28	61	7.5	12.8	10.6	4.1	2.9	**At Risk**	**At Risk**	1.9	**0.6**	57.1	1.2	**0.5**	35
	2*	16.4	17.9	10.8	28	42	7.6	>50.0	>50.0	6.3	5.1	**At Risk**	**At Risk**	3.0	**0.8**	78.4	1.6	**0.9**	35
	2*	16.4	17.9	10.8	28	44	7.3	43.4	41.3	6.0	4.8	**At Risk**	**At Risk**	2.9	**0.8**	77.4	1.6	**0.8**	36
LNR-12	2	16.4	17.9	10.8	28	42	4.6	>50.0	>50.0	6.3	5.1	Stable	Stable	3.6	1.4	--	2.1	1.2	***51***
	SS	18.0	19.1	7.7	26	57	6.1	9.3	7.9	3.0	2.2	**At Risk**	**At Risk**	1.8	**0.5**	54.7	**1.0**	**0.5**	30
	SS	18.0	19.1	7.7	26	32	5.2	>50.0	>50.0	5.6	4.8	Stable	**At Risk**	3.7	1.1	--	1.8	1.1	***35***
	SS	18.0	19.1	7.7	26	40	4.6	33.0	31.7	4.4	3.6	**At Risk**	**At Risk**	3.0	**0.9**	89.9	1.7	**1.0**	39
	SS	18.0	19.1	7.7	26	41	4.8	29.7	28.3	4.3	3.5	**At Risk**	**At Risk**	2.9	**0.9**	83.9	1.6	**0.9**	38
	SS	18.0	19.1	7.7	26	44	3.6	21.6	20.3	4.0	3.1	Stable	**At Risk**	2.9	1.1	--	1.7	**1.0**	***46***
	SS	18.0	19.1	7.7	26	32	3.1	>50.0	>50.0	5.6	4.8	Stable	Stable	4.5	1.8	--	2.2	1.4	***49***
	SS	18.0	19.1	7.7	26	44	5.0	22.7	21.3	4.0	3.2	**At Risk**	**At Risk**	2.6	**0.8**	77.1	1.5	**0.8**	37
	SS	18.0	19.1	7.7	26	43	4.7	25.6	24.2	4.1	3.3	**At Risk**	**At Risk**	2.8	**0.9**	82.1	1.6	**0.9**	39
LNR-13	2	16.4	17.9	10.8	28	36	5.6	>50.0	>50.0	7.3	6.1	Stable	Stable	3.8	1.3	--	2.0	1.2	***43***
	SS	15.0	17.4	12.8	25	33	5.6	>50.0	>50.0	9.9	8.4	Stable	Stable	4.6	1.8	--	2.2	1.3	***47***
	SS	15.0	17.4	12.8	25	39	5.7	>50.0	>50.0	8.4	6.9	Stable	Stable	3.9	1.5	--	2.0	1.2	***47***
	SS	15.0	17.4	12.8	25	38	5.4	>50.0	>50.0	8.7	7.2	Stable	Stable	4.1	1.6	--	2.1	1.3	***49***
	SS	15.0	17.4	12.8	25	36	5.7	>50.0	>50.0	9.1	7.6	Stable	Stable	4.2	1.6	--	2.1	1.2	***47***
LNR-14	2	16.4	17.9	10.8	28	30	8.2	>50.0	>50.0	9.1	7.8	Stable	**At Risk**	4.2	1.1	--	2.0	1.1	***34***
	SS	18.3	19.0	23.8	20	33	8.9	>50.0	>50.0	17.1	14.6	Stable	Stable	4.1	1.9	--	2.0	1.4	***54***
	SS	18.3	19.0	23.8	20	30	8.0	>50.0	>50.0	18.8	16.3	Stable	Stable	4.8	2.4	--	2.2	1.6	***59***
	SS	18.3	19.0	23.8	20	22	8.2	>50.0	>50.0	25.4	22.9	Stable	Stable	6.3	3.1	--	2.5	1.9	***58***
	SS	18.3	19.0	23.8	20	29	7.0	>50.0	>50.0	19.2	16.7	Stable	Stable	5.2	2.7	--	2.4	1.7	***64***
	SS	18.3	19.0	23.8	20	39	8.6	>50.0	>50.0	14.1	11.6	Stable	Stable	3.4	1.6	--	1.9	1.3	***56***
	SS	18.3	19.0	23.8	20	26	8.3	>50.0	>50.0	21.4	18.9	Stable	Stable	5.3	2.6	--	2.3	1.7	***57***
LNR-15	2	16.4	17.9	10.8	28	33	4.8	>50.0	>50.0	8.2	6.9	Stable	Stable	4.5	1.7	--	2.3	1.4	***50***
	SS	18.8	19.5	12.9	29	30	5.0	>50.0	>50.0	9.8	8.5	Stable	Stable	4.9	2.0	--	2.5	1.6	***54***
	SS	18.8	19.5	12.9	29	32	4.4	>50.0	>50.0	9.3	7.9	Stable	Stable	4.9	2.1	--	2.6	1.7	***60***
	SS	18.8	19.5	12.9	29	31	5.1	>50.0	>50.0	9.6	8.3	Stable	Stable	4.8	1.9	--	2.4	1.6	***53***
	SS	18.8	19.5	12.9	29	39	4.7	>50.0	>50.0	7.5	6.1	Stable	Stable	3.8	1.6	--	2.2	1.5	***56***
LNR-16	2	16.4	17.9	10.8	28	43	5.5	46.9	44.7	6.2	4.9	Stable	**At Risk**	3.2	1.1	--	1.8	**1.0**	***44***
	SS	16.8	18.4	10.2	37	33	5.7	>50.0	>50.0	7.4	6.3	Stable	Stable	4.6	1.3	--	2.5	1.3	***44***
	SS	16.8	18.4	10.2	37	59	4.7	22.3	19.8	3.9	2.8	**At Risk**	**At Risk**	2.6	**0.8**	76.7	1.7	**0.8**	51
	SS	16.8	18.4	10.2	37	43	5.8	>50.0	>50.0	5.7	4.6	**At Risk**	**At Risk**	3.5	**1.0**	94.6	2.1	**1.0**	***44***
	SS	16.8	18.4	10.2	37	37	5.8	>50.0	>50.0	6.6	5.5	Stable	**At Risk**	4.1	1.1	--	2.3	1.2	***43***
	SS	16.8	18.4	10.2	37	38	5.7	>50.0	>50.0	6.4	5.3	Stable	**At Risk**	4.0	1.1	--	2.3	1.2	***44***
	SS	16.8	18.4	10.2	37	37	5.7	>50.0	>50.0	6.6	5.5	Stable	**At Risk**	4.1	1.2	--	2.3	1.2	***44***
	SS	16.8	18.4	10.2	37	32	5.5	>50.0	>50.0	7.6	6.5	Stable	Stable	4.8	1.4	--	2.6	1.4	***45***
	SS	16.8	18.4	10.2	37	42	4.4	>50.0	>50.0	5.8	4.7	Stable	Stable	3.9	1.3	--	2.4	1.3	***52***
	SS	16.8	18.4	10.2	37	48	5.7	>50.0	>50.0	5.0	3.9	**At Risk**	**At Risk**	3.0	**0.9**	80.5	1.8	**0.9**	44
	SS	16.8	18.4	10.2	37	59	5.8	22.0	19.6	3.9	2.8	**At Risk**	**At Risk**	2.4	**0.7**	65.7	1.5	**0.6**	43

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb} (kN/m^3)	Saturated soil unit weight, γ_{sat} (kN/m^3)	Effective cohesion, c' (kPa)	Friction angle, ϕ (°)	Vertically weighted bank angle (°)	Bank height (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Without tension cracks	With tension cracks	Ambient CW0--BW0 (F_S)	Saturated CW0--BW100 (F_S)	BWyy at which F_S = 1 for CW0 (%)	Ambient (F_S)	Saturated (F_S)	Maximum expected stable bank angle (saturated) (°)
Little Nemaha River Basin--Continued																			
LNR-17	2	16.4	17.9	10.8	28	34	6.3	>50.0	>50.0	7.8	6.6	Stable	Stable	3.9	1.2	--	2.0	1.1	***38***
	SS	18.1	18.4	15.5	28	45	6.3	47.8	44.9	8.1	6.4	Stable	Stable	3.1	1.3	--	1.8	1.1	***50***
	SS	18.1	18.4	15.5	28	38	6.4	>50.0	>50.0	9.9	8.2	Stable	Stable	3.8	1.6	--	2.1	1.3	***49***
	SS	18.1	18.4	15.5	28	32	6.4	>50.0	>50.0	11.7	10.0	Stable	Stable	4.5	1.8	--	2.3	1.4	***49***
	SS	18.1	18.4	15.5	28	34	6.9	>50.0	>50.0	10.9	9.2	Stable	Stable	4.1	1.6	--	2.1	1.3	***48***
	SS	18.1	18.4	15.5	28	27	5.6	>50.0	>50.0	14.0	12.3	Stable	Stable	5.7	2.5	--	2.7	1.8	***56***
	SS	18.1	18.4	15.5	28	31	6.5	>50.0	>50.0	12.3	10.6	Stable	Stable	4.7	1.9	--	2.3	1.5	***49***
LNR-18	2	16.4	17.9	10.8	28	37	2.3	>50.0	>50.0	7.2	6.0	Stable	Stable	5.9	3.2	--	3.6	2.6	***90***
	SS	17.6	18.2	12.2	23	53	2.4	15.2	13.1	5.4	4.0	Stable	Stable	3.7	2.2	--	2.7	2.0	***90***
	SS	17.6	18.2	12.2	23	28	2.0	>50.0	>50.0	10.8	9.4	Stable	Stable	8.3	5.3	--	4.2	3.4	***90***
	SS	17.6	18.2	12.2	23	41	2.4	34.8	32.7	7.2	5.9	Stable	Stable	4.9	3.0	--	3.1	2.4	***90***
	SS	17.6	18.2	12.2	23	27	2.1	>50.0	>50.0	11.4	10.0	Stable	Stable	8.4	5.3	--	4.1	3.3	***90***
LNR-19	2	16.4	17.9	10.8	28	25	3.1	>50.0	>50.0	11.1	9.9	Stable	Stable	7.6	3.6	--	3.3	2.2	***63***
	2*	16.4	17.9	10.8	28	35	2.9	>50.0	>50.0	7.8	6.6	Stable	Stable	5.5	2.7	--	2.9	1.9	***69***
	2*	16.4	17.9	10.8	28	19	3.2	>50.0	>50.0	14.6	13.4	Stable	Stable	9.8	4.5	--	3.6	2.5	***62***
	2*	16.4	17.9	10.8	28	20	3.1	>50.0	>50.0	13.8	12.6	Stable	Stable	9.5	4.4	--	3.6	2.4	***63***
	2*	16.4	17.9	10.8	28	25	3.8	>50.0	>50.0	11.0	9.8	Stable	Stable	6.9	2.9	--	3.1	2.0	***58***
	2*	16.4	17.9	10.8	28	27	2.8	>50.0	>50.0	10.2	9.0	Stable	Stable	7.5	3.7	--	3.5	2.4	***74***
	2*	16.4	17.9	10.8	28	23	2.9	>50.0	>50.0	11.9	10.7	Stable	Stable	8.4	4.0	--	3.5	2.4	***66***
Big Nemaha River Basin																			
BNR-1	2	16.4	17.9	10.8	28	50	3.8	24.0	21.8	5.2	4.0	Stable	Stable	3.2	1.4	--	2.0	1.2	***58***
	SS	12.9	16.5	10.5	31	41	3.8	>50.0	>50.0	6.8	5.5	Stable	Stable	4.8	1.8	--	2.7	1.4	***58***
	SS	12.9	16.5	10.5	31	60	3.6	18.9	16.0	4.4	3.1	Stable	**At Risk**	3.2	1.2	--	2.1	**1.0**	59
	SS	12.9	16.5	10.5	31	42	3.8	>50.0	>50.0	6.6	5.3	Stable	Stable	4.7	1.8	--	2.7	1.4	***58***
	SS	12.9	16.5	10.5	31	46	3.7	>50.0	>50.0	5.9	4.7	Stable	Stable	4.2	1.6	--	2.5	1.3	***58***
	SS	12.9	16.5	10.5	31	56	4.0	24.0	21.2	4.8	3.5	Stable	**At Risk**	3.3	1.2	--	2.1	**1.0**	***56***
	SS	12.9	16.5	10.5	31	55	3.9	25.8	23.0	4.9	3.6	Stable	**At Risk**	3.4	1.3	--	2.2	1.1	***57***
BNR-2	2	16.4	17.9	10.8	28	38	5.1	>50.0	>50.0	6.9	5.7	Stable	Stable	3.8	1.4	--	2.1	1.2	***47***
	SS	16.0	18.8	7.0	33	31	5.3	>50.0	>50.0	5.4	4.7	Stable	**At Risk**	4.4	1.0	--	2.2	1.2	***37***
	SS	16.0	18.8	7.0	33	36	5.1	>50.0	>50.0	4.6	3.8	**At Risk**	**At Risk**	3.8	**0.9**	86.5	2.0	1.1	***38***
	SS	16.0	18.8	7.0	33	44	5.1	>50.0	>50.0	3.6	2.9	**At Risk**	**At Risk**	3.0	**0.7**	72.7	1.7	**0.8**	38
	SS	16.0	18.8	7.0	33	42	5.2	>50.0	>50.0	3.9	3.2	**At Risk**	**At Risk**	3.2	**0.8**	74.7	1.8	**0.9**	37
	SS	16.0	18.8	7.0	33	36	4.9	>50.0	>50.0	4.5	3.8	**At Risk**	**At Risk**	3.8	**0.9**	87.9	2.1	1.1	***39***
	SS	16.0	18.8	7.0	33	41	4.9	>50.0	>50.0	4.0	3.2	**At Risk**	**At Risk**	3.3	**0.8**	77.6	1.9	**0.9**	39
BNR-3	2	16.4	17.9	10.8	28	38	5.1	>50.0	>50.0	7.1	5.9	Stable	Stable	3.8	1.4	--	2.1	1.2	***47***
	SS	18.9	20.1	5.4	32	34	4.6	>50.0	>50.0	3.5	2.9	**At Risk**	**At Risk**	3.4	**0.8**	76.1	1.8	γsat	γsat
	SS	18.9	20.1	5.4	32	50	4.6	15.7	14.7	2.3	1.8	**At Risk**	**At Risk**	2.2	**0.5**	59.3	1.3	γsat	γsat
	SS	18.9	20.1	5.4	32	33	5.3	>50.0	>50.0	3.6	3.1	**At Risk**	**At Risk**	3.4	**0.7**	72.2	1.8	γsat	γsat
	SS	18.9	20.1	5.4	32	33	5.2	>50.0	>50.0	3.6	3.1	**At Risk**	**At Risk**	3.4	**0.7**	73.7	1.8	γsat	γsat
	SS	18.9	20.1	5.4	32	34	5.6	>50.0	>50.0	3.5	3.0	**At Risk**	**At Risk**	3.3	**0.6**	69.8	1.7	γsat	γsat
	SS	18.9	20.1	5.4	32	41	5.4	>50.0	>50.0	2.9	2.4	**At Risk**	**At Risk**	2.7	**0.5**	63.8	1.5	γsat	γsat

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Big Nemaha River Basin--Continued											
BNR-4	2	16.4	17.9	10.8	28	48	4.6	27.9	25.7	5.4	4.2	Stable	**At Risk**	3.0	1.2	--	1.9	1.1	***51***
	SS	17.5	18.6	18.5	16	42	4.8	27.2	24.3	10.3	8.3	Stable	Stable	3.8	2.1	--	2.1	1.6	***73***
	SS	17.5	18.6	18.5	16	43	4.7	26.3	23.4	10.1	8.2	Stable	Stable	3.8	2.1	--	2.1	1.6	***74***
	SS	17.5	18.6	18.5	16	60	4.2	12.9	10.0	6.9	5.0	Stable	Stable	2.8	1.7	--	1.9	1.4	***79***
	SS	17.5	18.6	18.5	16	48	4.6	20.1	17.3	8.9	6.9	Stable	Stable	3.3	1.9	--	2.0	1.5	***75***
BNR-5	2	16.4	17.9	10.8	28	24	5.6	>50.0	>50.0	11.5	10.3	Stable	Stable	6.0	2.1	--	2.6	1.6	***43***
	SS	15.6	18.6	8.7	34	18	3.6	>50.0	>50.0	11.6	10.7	Stable	Stable	9.7	3.3	--	3.9	2.4	***53***
	SS	15.6	18.6	8.7	34	29	7.6	>50.0	>50.0	7.2	6.3	**At Risk**	**At Risk**	4.6	**0.9**	90.6	2.3	1.2	***34***
BNR-6	2	16.4	17.9	10.8	28	43	6.8	45.7	43.5	6.1	4.9	**At Risk**	**At Risk**	3.0	**0.9**	82.9	1.6	**0.9**	37
	SS	17.6	18.6	15.3	21	22	6.4	>50.0	>50.0	17.0	15.3	Stable	Stable	6.1	2.6	--	2.3	1.6	***45***
	SS	17.6	18.6	15.3	21	64	6.5	10.8	8.3	5.3	3.6	**At Risk**	**At Risk**	1.9	**0.8**	73.8	1.2	**0.7**	45
	SS	17.6	18.6	15.3	21	33	7.5	>50.0	>50.0	10.9	9.3	Stable	Stable	3.7	1.5	--	1.8	1.2	***42***
	SS	17.6	18.6	15.3	21	53	6.7	16.7	14.2	6.6	4.9	**At Risk**	**At Risk**	2.3	**1.0**	93.8	1.4	**0.8**	45
BNR-7	2	16.4	17.9	10.8	28	43	5.1	45.5	43.3	6.1	4.9	Stable	**At Risk**	3.3	1.2	--	1.9	1.1	***47***
	SS	18.0	18.9	21.0	27	39	5.5	>50.0	>50.0	12.7	10.4	Stable	Stable	4.6	2.3	--	2.6	1.8	***70***
	SS	18.0	18.9	21.0	27	52	4.9	35.4	31.6	9.1	6.9	Stable	Stable	3.5	1.9	--	2.4	1.6	***75***
	SS	18.0	18.9	21.0	27	39	4.7	>50.0	>50.0	12.4	10.2	Stable	Stable	4.9	2.6	--	2.9	2.1	***76***
	SS	18.0	18.9	21.0	27	42	5.3	>50.0	>50.0	11.5	9.3	Stable	Stable	4.2	2.2	--	2.6	1.8	***71***
BNR-8	2	16.4	17.9	10.8	28	42	4.5	>50.0	49.7	6.3	5.1	Stable	Stable	3.6	1.4	--	2.1	1.2	***52***
	SS	18.4	19.1	15.0	24	62	5.0	12.1	9.6	5.2	3.6	Stable	**At Risk**	2.2	1.0	--	1.5	**1.0**	60
	SS	18.4	19.1	15.0	24	43	4.4	35.8	33.3	8.0	6.4	Stable	Stable	3.6	1.8	--	2.2	1.5	***66***
	SS	18.4	19.1	15.0	24	16	4.2	>50.0	>50.0	22.8	21.3	Stable	Stable	10.7	5.5	--	3.5	2.6	***68***
	SS	18.4	19.1	15.0	24	47	4.6	27.0	24.5	7.3	5.7	Stable	Stable	3.2	1.6	--	2.0	1.4	***64***
BNR-9	2	16.4	17.9	10.8	28	31	10.5	>50.0	>50.0	8.7	7.5	**At Risk**	**At Risk**	3.7	**0.8**	78.8	1.8	**0.9**	29
	SS	19.0	19.2	22.5	24	28	10.7	>50.0	>50.0	18.6	16.2	Stable	Stable	4.4	1.7	--	2.1	1.4	***45***
	SS	19.0	19.2	22.5	24	41	11.2	>50.0	>50.0	12.4	10.1	Stable	**At Risk**	2.9	1.1	--	1.6	**1.0**	***43***
	SS	19.0	19.2	22.5	24	22	10.5	>50.0	>50.0	23.7	21.4	Stable	Stable	5.7	2.3	--	2.4	1.7	***46***
	SS	19.0	19.2	22.5	24	32	9.4	>50.0	>50.0	16.3	13.9	Stable	Stable	4.1	1.7	--	2.1	1.4	***51***
BNR-10	2	16.4	17.9	10.8	28	42	2.5	>50.0	>50.0	6.3	5.1	Stable	Stable	4.9	2.5	--	3.2	2.2	***86***
	SS	15.5	17.3	11.7	20	41	2.5	26.7	24.5	7.2	5.9	Stable	Stable	5.0	2.8	--	3.0	2.2	***90***
	SS	15.5	17.3	11.7	20	40	2.1	29.1	27.0	7.4	6.1	Stable	Stable	5.7	3.5	--	3.6	2.7	***90***
	SS	15.5	17.3	11.7	20	41	2.6	26.8	24.7	7.2	5.9	Stable	Stable	4.9	2.8	--	2.9	2.1	***90***
	SS	15.5	17.3	11.7	20	37	2.2	36.0	33.9	8.0	6.6	Stable	Stable	6.1	3.7	--	3.6	2.7	***90***
	SS	15.5	17.3	11.7	20	44	2.8	22.6	20.5	6.8	5.4	Stable	Stable	4.3	2.4	--	2.5	1.7	***78***
	SS	15.5	17.3	11.7	20	48	2.7	17.9	15.8	6.1	4.8	Stable	Stable	4.1	2.3	--	2.6	1.9	***86***
BNR-11	2	16.4	17.9	10.8	28	47	4.6	31.2	29.0	5.6	4.4	Stable	**At Risk**	3.1	1.2	--	1.9	1.1	***51***
	SS	16.6	18.0	20.3	24	48	4.3	38.7	34.9	10.2	8.0	Stable	Stable	4.2	2.4	--	2.7	1.9	***80***
	SS	16.6	18.0	20.3	24	57	4.7	23.2	19.4	8.4	6.1	Stable	Stable	3.3	1.8	--	2.3	1.5	***77***
	SS	16.6	18.0	20.3	24	48	4.6	38.3	34.5	10.2	7.9	Stable	Stable	4.0	2.2	--	2.6	1.8	***78***
	SS	16.6	18.0	20.3	24	35	4.7	>50.0	>50.0	14.2	11.9	Stable	Stable	5.5	3.0	--	3.0	2.1	***76***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
								Big Nemaha River Basin--Continued											
BNR-12	2	16.4	17.9	10.8	28	39	2.4	>50.0	>50.0	6.8	5.6	Stable	Stable	5.4	2.9	--	3.4	2.4	***90***
	SS	18.6	19.7	12.4	33	42	2.2	>50.0	>50.0	6.6	5.3	Stable	Stable	5.5	3.0	--	3.8	2.8	***90***
	SS	18.6	19.7	12.4	33	37	3.7	>50.0	>50.0	7.5	6.3	Stable	Stable	4.7	2.1	--	2.7	1.8	***64***
	SS	18.6	19.7	12.4	33	53	2.4	28.0	25.6	5.0	3.8	Stable	Stable	4.0	2.1	--	3.1	2.2	***90***
	SS	18.6	19.7	12.4	33	23	2.1	>50.0	>50.0	12.2	11.0	Stable	Stable	10.3	5.7	--	5.0	3.9	***90***
	SS	18.6	19.7	12.4	33	38	2.2	>50.0	>50.0	7.4	6.1	Stable	Stable	6.0	3.3	--	3.9	2.9	***90***
	SS	18.6	19.7	12.4	33	41	1.7	>50.0	>50.0	6.7	5.4	Stable	Stable	6.5	3.9	--	4.5	3.4	***90***
BNR-13	2	16.4	17.9	10.8	28	45	8.3	37.7	35.5	5.8	4.6	**At Risk**	**At Risk**	2.6	**0.7**	69.8	1.5	**0.7**	33
	SS	18.6	18.8	10.1	25	52	7.0	13.5	11.8	4.4	3.3	**At Risk**	**At Risk**	2.0	**0.6**	63.1	1.1	**0.6**	32
	SS	18.6	18.8	10.1	25	28	8.3	>50.0	>50.0	8.5	7.5	Stable	**At Risk**	3.8	1.0	--	1.7	**1.0**	***29***
	SS	18.6	18.8	10.1	25	41	6.5	31.5	29.8	5.7	4.7	**At Risk**	**At Risk**	2.7	**0.9**	81.9	1.4	**0.8**	34
	SS	18.6	18.8	10.1	25	59	9.6	9.7	8.0	3.8	2.7	**At Risk**	**Unstable**	1.6	**0.4**	45.2	**0.9**	**0.4**	27
	SS	18.6	18.8	10.1	25	48	8.4	17.4	15.7	4.8	3.7	**At Risk**	**At Risk**	2.1	**0.6**	61.2	1.1	**0.6**	29
	SS	18.6	18.8	10.1	25	41	9.7	33.2	31.5	5.8	4.7	**At Risk**	**At Risk**	2.4	**0.6**	65.1	1.3	**0.7**	27
BNR-14	2	16.4	17.9	10.8	28	28	7.4	>50.0	>50.0	9.7	8.5	Stable	Stable	4.6	1.3	--	2.1	1.2	***36***
	SS	17.9	18.7	15.8	34	31	7.8	>50.0	>50.0	12.3	10.6	Stable	Stable	4.8	1.6	--	2.5	1.5	***48***
	SS	17.9	18.7	15.8	34	25	7.1	>50.0	>50.0	14.9	13.2	Stable	Stable	6.1	2.1	--	3.0	1.9	***50***
BNR-15	2	16.4	17.9	10.8	28	28	4.0	>50.0	>50.0	9.8	8.6	Stable	Stable	6.0	2.5	--	2.8	1.8	***57***
	SS	18.4	19.2	11.2	30	28	4.0	>50.0	>50.0	9.3	8.1	Stable	Stable	5.6	2.3	--	2.8	1.9	***57***
	SS	18.4	19.2	11.2	30	27	3.9	>50.0	>50.0	9.7	8.6	Stable	Stable	5.9	2.5	--	2.9	2.0	***58***
BNR-16	2	16.4	17.9	10.8	28	37	9.4	>50.0	>50.0	7.2	6.0	**At Risk**	**At Risk**	3.1	**0.8**	74.0	1.6	**0.8**	30
	SS	17.4	18.6	7.6	33	28	7.9	>50.0	>50.0	6.4	5.6	**At Risk**	**At Risk**	4.2	**0.8**	79.6	2.1	1.1	***31***
	SS	17.4	18.6	7.6	33	36	9.7	>50.0	>50.0	5.1	4.3	**At Risk**	**At Risk**	3.2	**0.5**	63.1	1.7	**0.8**	29
	SS	17.4	18.6	7.6	33	25	9.6	>50.0	>50.0	7.4	6.6	**At Risk**	**At Risk**	4.7	**0.8**	78.9	2.3	1.2	***29***
	SS	17.4	18.6	7.6	33	46	9.3	43.6	42.0	3.9	3.1	**At Risk**	**At Risk**	2.4	**0.4**	55.0	1.4	**0.6**	29
	SS	17.4	18.6	7.6	33	34	9.7	>50.0	>50.0	5.4	4.6	**At Risk**	**At Risk**	3.4	**0.6**	65.4	1.8	**0.8**	29
	SS	17.4	18.6	7.6	33	54	10.1	17.5	15.9	3.2	2.4	**At Risk**	**At Risk**	1.9	**0.3**	47.6	1.1	**0.3**	28
BNR-17	2	16.4	17.9	10.8	28	34	7.5	>50.0	>50.0	7.9	6.7	Stable	**At Risk**	3.7	1.0	--	1.9	**1.0**	***35***
	SS	16.9	17.8	7.8	24	30	7.8	>50.0	>50.0	6.5	5.6	**At Risk**	**At Risk**	3.5	**0.8**	79.6	1.6	**0.8**	26
	SS	16.9	17.8	7.8	24	35	8.5	>50.0	>50.0	5.5	4.6	**At Risk**	**At Risk**	2.9	**0.6**	68.1	1.4	**0.7**	25
	SS	16.9	17.8	7.8	24	27	6.6	>50.0	>50.0	7.4	6.5	Stable	**At Risk**	4.1	1.1	--	1.8	**1.0**	***28***
	SS	16.9	17.8	7.8	24	33	7.3	>50.0	>50.0	6.0	5.1	**At Risk**	**At Risk**	3.3	**0.8**	77.8	1.5	**0.8**	27
	SS	16.9	17.8	7.8	24	34	7.8	>50.0	>50.0	5.8	4.9	**At Risk**	**At Risk**	3.1	**0.7**	73.0	1.5	**0.8**	26
	SS	16.9	17.8	7.8	24	36	7.1	48.0	46.6	5.4	4.5	**At Risk**	**At Risk**	3.0	**0.8**	73.9	1.4	**0.8**	27
	SS	16.9	17.8	7.8	24	47	7.5	15.7	14.3	4.0	3.1	**At Risk**	**At Risk**	2.2	**0.5**	59.4	1.1	**0.6**	27
	SS	16.9	17.8	7.8	24	30	7.5	>50.0	>50.0	6.5	5.6	**At Risk**	**At Risk**	3.5	**0.9**	80.7	1.6	**0.9**	27
	SS	16.9	17.8	7.8	24	34	7.7	>50.0	>50.0	5.8	4.9	**At Risk**	**At Risk**	3.1	**0.7**	73.3	1.5	**0.8**	26
	SS	16.9	17.8	7.8	24	34	7.4	>50.0	>50.0	5.7	4.8	**At Risk**	**At Risk**	3.1	**0.8**	74.4	1.5	**0.8**	27

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb}	Saturated soil unit weight, γ_{sat}	Effective cohesion, c'	Friction angle, ϕ	Vertically weighted bank angle	Bank height	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Critical bank height, H_c	Critical bank height with tension crack, H_{cz}	Without tension cracks	With tension cracks	Ambient CW0--BW0	Saturated CW0--BW100	BWyy at which F_S = 1 for CW0	Ambient	Saturated	Maximum expected stable bank angle (saturated)
		(kN/m^3)	(kN/m^3)	(kPa)	(°)	(°)	(m)	(m)	(m)	(m)	(m)			(F_S)	(F_S)	(%)	(F_S)	(F_S)	(°)
										Big Blue River Basin									
BBR-1	1	15.9	17.6	13.6	26	36	3.4	>50.0	>50.0	9.4	7.8	Stable	Stable	5.5	2.8	--	2.9	1.9	***72***
	SS	17.3	18.4	18.0	22	36	4.2	>50.0	>50.0	12.2	10.2	Stable	Stable	5.2	2.9	--	2.8	2.0	***77***
	SS	17.3	18.4	18.0	22	29	2.9	>50.0	>50.0	14.9	13.0	Stable	Stable	8.1	5.2	--	3.6	2.8	***90***
	SS	17.3	18.4	18.0	22	50	3.6	25.5	22.4	8.5	6.5	Stable	Stable	4.0	2.4	--	2.5	1.8	***83***
	SS	17.3	18.4	18.0	22	21	3.2	>50.0	>50.0	20.7	18.7	Stable	Stable	10.6	6.5	--	3.8	3.0	***86***
	SS	17.3	18.4	18.0	22	58	3.3	17.2	14.2	7.1	5.2	Stable	Stable	3.5	2.1	--	2.4	1.7	***85***
	SS	17.3	18.4	18.0	22	31	2.7	>50.0	>50.0	14.0	12.0	Stable	Stable	7.9	5.1	--	3.9	3.1	***90***
	SS	17.3	18.4	18.0	22	30	3.4	>50.0	>50.0	14.8	12.8	Stable	Stable	7.2	4.4	--	3.3	2.5	***84***
	SS	17.3	18.4	18.0	22	42	3.1	40.5	37.5	10.1	8.1	Stable	Stable	5.2	3.2	--	2.9	2.2	***87***
	SS	17.3	18.4	18.0	22	39	3.4	>50.0	49.6	10.9	9.0	Stable	Stable	5.3	3.2	--	2.9	2.2	***84***
	SS	17.3	18.4	18.0	22	32	4.1	>50.0	>50.0	13.5	11.5	Stable	Stable	5.9	3.3	--	2.9	2.1	***78***
	SS	17.3	18.4	18.0	22	39	3.1	>50.0	49.8	11.0	9.0	Stable	Stable	5.7	3.6	--	3.0	2.3	***87***
	SS	17.3	18.4	18.0	22	25	3.4	>50.0	>50.0	17.7	15.7	Stable	Stable	8.6	5.2	--	3.5	2.7	***84***
	SS	17.3	18.4	18.0	22	51	3.3	24.1	21.0	8.3	6.3	Stable	Stable	4.1	2.5	--	2.6	1.9	***85***
	SS	17.3	18.4	18.0	22	27	3.4	>50.0	>50.0	16.5	14.6	Stable	Stable	8.1	4.9	--	3.4	2.6	***84***
BBR-2	1	15.9	17.6	13.6	26	47	0.9	33.8	31.0	7.1	5.6	Stable	Stable	10.2	7.6	--	bh	bh	bh
	SS	16.0	17.6	6.4	29	50	0.9	15.1	13.8	3.1	2.4	Stable	Stable	5.6	3.5	--	bh	bh	bh
	SS	16.0	17.6	6.4	29	46	0.9	20.9	19.5	3.4	2.7	Stable	Stable	6.3	4.0	--	bh	bh	bh
	SS	16.0	17.6	6.4	29	52	0.9	13.1	11.8	3.0	2.2	Stable	Stable	5.2	3.1	--	bh	bh	bh
	SS	16.0	17.6	6.4	29	44	0.9	26.7	25.3	3.6	2.9	Stable	Stable	6.6	4.1	--	bh	bh	bh
	SS	16.0	17.6	6.4	29	52	1.1	13.8	12.4	3.0	2.3	Stable	Stable	4.7	2.7	--	3.1	2.2	***90***
	SS	16.0	17.6	6.4	29	38	0.9	>50.0	>50.0	4.3	3.6	Stable	Stable	7.6	4.6	--	bh	bh	bh
BBR-3	1	15.9	17.6	13.6	26	50	1.7	27.0	24.2	6.6	5.1	Stable	Stable	5.9	3.8	--	4.6	3.4	***90***
	SS	16.7	17.6	7.2	23	64	1.7	5.9	4.5	2.6	1.8	Stable	Stable	2.8	1.6	--	2.4	1.7	***90***
	SS	16.7	17.6	7.2	23	46	1.5	14.2	12.9	3.8	3.0	Stable	Stable	4.3	2.5	--	2.9	2.2	***90***
	SS	16.7	17.6	7.2	23	43	2.1	18.5	17.2	4.2	3.4	Stable	Stable	3.9	2.0	--	2.5	1.8	***83***
	SS	16.7	17.6	7.2	23	71	1.4	4.5	3.2	2.3	1.5	Stable	Stable	2.8	1.7	--	2.5	1.8	***90***
	SS	16.7	17.6	7.2	23	41	1.9	21.0	19.7	4.3	3.5	Stable	Stable	4.3	2.3	--	2.7	2.0	***89***
	SS	16.7	17.6	7.2	23	36	1.9	39.5	38.2	5.1	4.3	Stable	Stable	5.0	2.7	--	2.9	2.1	***89***
BBR-4	3	16.5	18.1	6.7	30	36	3.0	>50.0	>50.0	4.5	3.8	Stable	Stable	4.2	1.5	--	2.2	1.3	***46***
	SS	17.9	18.7	8.9	28	37	2.8	>50.0	>50.0	5.7	4.7	Stable	Stable	4.4	2.0	--	2.5	1.7	***64***
	SS	17.9	18.7	8.9	28	40	3.2	47.1	45.4	5.2	4.3	Stable	Stable	3.8	1.6	--	2.1	1.4	***54***
	SS	17.9	18.7	8.9	28	32	2.9	>50.0	>50.0	6.7	5.7	Stable	Stable	5.1	2.3	--	2.5	1.7	***59***
	SS	17.9	18.7	8.9	28	35	3.4	>50.0	>50.0	6.1	5.2	Stable	Stable	4.3	1.8	--	2.3	1.5	***52***
	SS	17.9	18.7	8.9	28	38	2.8	>50.0	>50.0	5.5	4.6	Stable	Stable	4.2	1.9	--	2.4	1.6	***62***
	SS	17.9	18.7	8.9	28	41	2.9	42.9	41.2	5.1	4.2	Stable	Stable	3.9	1.7	--	2.2	1.4	***58***
	SS	17.9	18.7	8.9	28	37	3.0	>50.0	>50.0	5.8	4.8	Stable	Stable	4.4	2.0	--	2.3	1.5	***57***
	SS	17.9	18.7	8.9	28	32	3.1	>50.0	>50.0	6.8	5.8	Stable	Stable	5.0	2.2	--	2.5	1.6	***55***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb} (kN/m^3)	Saturated soil unit weight, γ_{sat} (kN/m^3)	Effective cohesion, c' (kPa)	Friction angle, ϕ (°)	Vertically weighted bank angle (°)	Bank height (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Without tension cracks	With tension cracks	Ambient CW0--BW0 (F_S)	Saturated CW0--BW100 (F_S)	BWyy at which F_S = 1 for CW0 (%)	Ambient (F_S)	Saturated (F_S)	Maximum expected stable bank angle (saturated) (°)
									Big Blue River Basin--Continued										
BBR-5	3	16.5	18.1	6.7	30	39	4.1	>50.0	>50.0	4.2	3.4	Stable	**At Risk**	3.4	1.0	--	1.9	**1.0**	***40***
	SS	17.2	18.6	14.1	40	40	3.9	>50.0	>50.0	8.4	6.9	Stable	Stable	5.2	2.2	--	3.2	2.0	***67***
	SS	17.2	18.6	14.1	40	38	4.1	>50.0	>50.0	8.8	7.3	Stable	Stable	5.3	2.1	--	3.3	2.0	***65***
	SS	17.2	18.6	14.1	40	33	5.0	>50.0	>50.0	10.4	8.9	Stable	Stable	5.8	2.1	--	3.2	1.9	***59***
	SS	17.2	18.6	14.1	40	40	4.6	>50.0	>50.0	8.4	6.9	Stable	Stable	4.8	1.8	--	3.0	1.8	***62***
	SS	17.2	18.6	14.1	40	48	3.3	>50.0	>50.0	6.9	5.4	Stable	Stable	4.6	2.1	--	3.0	1.8	***71***
	SS	17.2	18.6	14.1	40	37	3.9	>50.0	>50.0	9.1	7.6	Stable	Stable	5.6	2.3	--	3.4	2.1	***67***
BBR-6	3	16.5	18.1	6.7	30	29	2.3	>50.0	>50.0	5.7	5.0	Stable	Stable	6.1	2.5	--	3.2	2.1	***73***
	SS	18.3	19.6	7.0	31	20	2.2	>50.0	>50.0	8.1	7.4	Stable	Stable	8.7	3.7	--	3.9	2.8	***75***
	SS	18.3	19.6	7.0	31	11	2.3	>50.0	>50.0	14.9	14.2	Stable	Stable	15.7	6.6	--	ba	ba	ba
	SS	18.3	19.6	7.0	31	24	2.2	>50.0	>50.0	6.7	6.0	Stable	Stable	7.2	3.0	--	3.6	2.5	***75***
	SS	18.3	19.6	7.0	31	28	1.7	>50.0	>50.0	5.8	5.1	Stable	Stable	7.1	3.5	--	3.8	2.7	***90***
	SS	18.3	19.6	7.0	31	39	2.2	>50.0	>50.0	4.1	3.3	Stable	Stable	4.4	1.9	--	2.8	1.9	***77***
	SS	18.3	19.6	7.0	31	32	2.3	>50.0	>50.0	5.0	4.3	Stable	Stable	5.2	2.2	--	2.9	2.0	***72***
	SS	18.3	19.6	7.0	31	43	2.5	39.1	37.7	3.6	2.9	Stable	Stable	3.6	1.4	--	2.3	1.5	***64***
	SS	18.3	19.6	7.0	31	34	2.7	>50.0	>50.0	4.6	3.9	Stable	Stable	4.5	1.7	--	2.5	1.6	***56***
BBR-7	3	16.5	18.1	6.7	30	37	2.8	>50.0	>50.0	4.4	3.7	Stable	Stable	4.3	1.6	--	2.4	1.4	***53***
	SS	14.9	17.5	4.3	30	42	2.8	31.2	30.2	2.6	2.1	**At Risk**	**At Risk**	3.3	**0.9**	84.7	1.8	**0.9**	37
	SS	14.9	17.5	4.3	30	24	2.7	>50.0	>50.0	4.7	4.2	Stable	Stable	6.2	1.8	--	2.7	1.6	***40***
	SS	14.9	17.5	4.3	30	43	3.1	28.4	27.4	2.5	2.0	**At Risk**	**At Risk**	3.1	**0.8**	76.8	1.6	**0.8**	32
	SS	14.9	17.5	4.3	30	41	2.4	34.8	33.8	2.6	2.1	Stable	**At Risk**	3.6	1.1	--	2.1	1.1	***46***
	SS	14.9	17.5	4.3	30	34	2.9	>50.0	>50.0	3.2	2.7	Stable	**At Risk**	4.1	1.1	--	2.0	**1.0**	***35***
	SS	14.9	17.5	4.3	30	38	2.9	>50.0	>50.0	2.9	2.4	Stable	**At Risk**	3.7	1.0	--	1.9	**1.0**	36
BBR-8	3	16.5	18.1	6.7	30	35	4.5	>50.0	>50.0	4.7	3.9	Stable	**At Risk**	3.7	1.0	--	2.0	1.1	***38***
	SS	17.4	18.1	12.6	19	46	5.0	17.8	15.7	6.5	5.1	Stable	Stable	2.8	1.3	--	1.6	1.1	***50***
	SS	17.4	18.1	12.6	19	21	4.3	>50.0	>50.0	14.8	13.4	Stable	Stable	6.9	3.5	--	2.6	1.9	***59***
	SS	17.4	18.1	12.6	19	38	3.7	31.0	29.0	8.1	6.7	Stable	Stable	4.1	2.2	--	2.1	1.6	***65***
	SS	17.4	18.1	12.6	19	33	5.3	>50.0	48.2	9.4	8.0	Stable	Stable	3.9	1.8	--	1.9	1.3	***47***
	SS	17.4	18.1	12.6	19	34	3.5	45.7	43.7	9.1	7.8	Stable	Stable	4.8	2.6	--	2.3	1.7	***67***
	SS	17.4	18.1	12.6	19	39	5.4	28.9	26.9	7.9	6.5	Stable	Stable	3.3	1.4	--	1.7	1.1	***45***
BBR-9	3	16.5	18.1	6.7	30	44	4.6	35.7	34.3	3.7	2.9	**At Risk**	**At Risk**	2.9	**0.8**	75.4	1.7	**0.8**	38
	SS	17.1	18.5	13.9	27	46	5.6	39.1	36.4	7.1	5.6	Stable	**At Risk**	3.2	1.3	--	1.9	1.1	***50***
	SS	17.1	18.5	13.9	27	26	5.8	>50.0	>50.0	13.0	11.5	Stable	Stable	5.8	2.2	--	2.6	1.7	***49***
	SS	17.1	18.5	13.9	27	63	3.2	13.7	11.0	4.9	3.4	Stable	Stable	2.9	1.5	--	2.0	1.3	***73***
	SS	17.1	18.5	13.9	27	40	3.8	>50.0	>50.0	8.2	6.7	Stable	Stable	4.5	2.2	--	2.6	1.7	***68***

Table 4. Results of Culmann, Agricultural Research Service (ARS), and indirect methods of bank-stability analysis based on few soil data and assumed homogeneous banks--Continued

								Culmann method						ARS method			Indirect method		
								Ambient conditions		Saturated conditions		Summary results		Summary results			Summary results		
Site ID	Soil group	Ambient soil unit weight, γ_{amb} (kN/m^3)	Saturated soil unit weight, γ_{sat} (kN/m^3)	Effective cohesion, c' (kPa)	Friction angle, ϕ (°)	Vertically weighted bank angle (°)	Bank height (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Critical bank height, H_c (m)	Critical bank height with tension crack, H_{cz} (m)	Without tension cracks	With tension cracks	Ambient CW0--BW0 (F_S)	Saturated CW0--BW100 (F_S)	BWyy at which F_S = 1 for CW0 (%)	Ambient (F_S)	Saturated (F_S)	Maximum expected stable bank angle (saturated) (°)
									Big Blue River Basin--Continued										
BBR-10	3	16.5	18.1	6.7	30	35	4.5	>50.0	>50.0	4.7	4.0	Stable	**At Risk**	3.8	1.1	--	2.0	1.1	***38***
	SS	18.3	19.1	2.5	38	31	4.4	>50.0	>50.0	1.9	1.6	**At Risk**	**At Risk**	3.7	**0.4**	60.7	1.9	**0.8**	28
	SS	18.3	19.1	2.5	38	44	4.0	47.0	46.5	1.3	1.0	**At Risk**	**At Risk**	2.5	**0.3**	52.0	1.4	**0.5**	29
	SS	18.3	19.1	2.5	38	58	4.2	6.0	5.5	1.0	0.7	**At Risk**	**At Risk**	1.8	**0.2**	42.3	**1.0**	**0.3**	28
	SS	18.3	19.1	2.5	38	28	6.0	>50.0	>50.0	2.1	1.9	**At Risk**	**At Risk**	4.0	**0.4**	59.3	2.0	**0.9**	26
	SS	18.3	19.1	2.5	38	41	4.3	>50.0	>50.0	1.4	1.1	**At Risk**	**At Risk**	2.7	**0.3**	52.8	1.5	**0.6**	28
	SS	18.3	19.1	2.5	38	29	4.5	>50.0	>50.0	2.0	1.8	**At Risk**	**At Risk**	4.0	**0.5**	61.3	2.0	**0.9**	28
	SS	18.3	19.1	2.5	38	25	4.3	>50.0	>50.0	2.4	2.1	**At Risk**	**At Risk**	4.7	**0.6**	67.9	2.4	1.2	***28***
	SS	18.3	19.1	2.5	38	25	3.8	>50.0	>50.0	2.4	2.1	**At Risk**	**At Risk**	4.8	**0.6**	70.4	2.5	1.3	***29***
BBR-11	3	16.5	18.1	6.7	30	39	3.9	>50.0	>50.0	4.2	3.4	Stable	**At Risk**	3.5	1.1	--	2.0	1.1	***42***
	SS	13.3	17.1	10.8	30	47	4.8	47.4	44.6	5.9	4.6	Stable	**At Risk**	3.7	1.2	--	2.2	1.1	***50***
	SS	13.3	17.1	10.8	30	36	3.9	>50.0	>50.0	7.9	6.6	Stable	Stable	5.4	2.0	--	2.9	1.6	***58***
	SS	13.3	17.1	10.8	30	41	3.6	>50.0	>50.0	6.7	5.4	Stable	Stable	4.8	1.9	--	2.7	1.5	***60***
	SS	13.3	17.1	10.8	30	34	3.9	>50.0	>50.0	8.3	7.0	Stable	Stable	5.7	2.1	--	2.9	1.6	***57***
	SS	13.3	17.1	10.8	30	43	3.1	>50.0	>50.0	6.4	5.2	Stable	Stable	5.0	2.1	--	2.8	1.6	***64***
	SS	13.3	17.1	10.8	30	34	3.8	>50.0	>50.0	8.2	6.9	Stable	Stable	5.7	2.2	--	2.9	1.7	***59***
BBR-12	3	16.5	18.1	6.7	30	53	3.6	14.3	12.9	3.0	2.2	**At Risk**	**At Risk**	2.6	**0.8**	77.0	1.6	**0.8**	43
	SS	18.0	19.0	12.7	30	67	2.9	10.8	8.4	4.0	2.7	Stable	**At Risk**	2.6	1.4	--	1.9	1.2	***74***
	SS	18.0	19.0	12.7	30	43	3.2	>50.0	>50.0	6.8	5.5	Stable	Stable	4.3	2.1	--	2.5	1.7	***68***
	SS	18.0	19.0	12.7	30	61	3.9	14.9	12.5	4.6	3.2	Stable	**At Risk**	2.6	1.2	--	1.8	1.1	***63***
	SS	18.0	19.0	12.7	30	42	4.2	>50.0	>50.0	6.9	5.6	Stable	Stable	3.8	1.7	--	2.3	1.5	***61***
BBR-13	3	16.5	18.1	6.7	30	36	5.8	>50.0	>50.0	4.5	3.8	**At Risk**	**At Risk**	3.4	**0.8**	75.6	1.7	**0.9**	30
	SS	15.1	18.5	2.3	38	46	5.8	35.4	34.8	1.2	0.9	**At Risk**	**At Risk**	2.5	**0.2**	45.8	1.2	**0.3**	26
	SS	15.1	18.5	2.3	38	30	5.7	>50.0	>50.0	1.8	1.6	**At Risk**	**At Risk**	4.0	**0.3**	56.4	1.9	**0.8**	26
	SS	15.1	18.5	2.3	38	39	5.4	>50.0	>50.0	1.4	1.2	**At Risk**	**At Risk**	3.1	**0.3**	50.9	1.5	**0.5**	26
	SS	15.1	18.5	2.3	38	30	6.3	>50.0	>50.0	1.9	1.6	**At Risk**	**At Risk**	4.0	**0.3**	55.3	1.9	**0.7**	26

Table 5. Number and percent of bank sections for each method of analysis by stability category and soil group

[Percent values are in bold font; because of rounding, the individual values may not add up to 100 for a given method or condition]

		Culmann												
		Without tension cracks			With tension cracks			ARS Method			Indirect Method			
Soil group	Number of bank sections	Unstable	At Risk	Stable	Unstable	At Risk	Stable	Unstable	At Risk	Stable	Unstable	At Risk	Stable	Out of range of method
1	72	0	5	67	0	6	66	0	5	67	0	6	58	8
		0	**7**	**93**	**0**	**8**	**92**	**0**	**7**	**93**	**0**	**8**	**81**	**11**
2	724	6	248	470	10	312	402	0	253	471	22	247	439	16
		1	**34**	**65**	**1**	**43**	**56**	**0**	**35**	**65**	**3**	**34**	**61**	**2**
3-4	112	1	37	74	3	49	60	0	38	74	6	33	66	7
		1	**33**	**66**	**3**	**44**	**54**	**0**	**34**	**66**	**5**	**29**	**59**	**6**
All	908	7	290	611	13	367	528	0	296	612	28	286	563	31
		1	**32**	**67**	**1**	**40**	**58**	**0**	**33**	**67**	**3**	**31**	**62**	**3**

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
Ambient Soil Unit Weight = 12.0 kilonewton per cubic meter							
0	10	1	0.7	0.3	0.2	0.2	0.2
0	10	3	0.7	0.3	0.2	0.1	0.1
0	10	6	0.7	0.3	0.2	0.1	0.1
0	10	12	0.7	0.3	0.2	0.1	0.1
0	25	1	1.8	0.8	0.5	0.5	0.6
0	25	3	1.8	0.9	0.5	0.3	0.2
0	25	6	1.8	0.9	0.5	0.3	0.1
0	25	12	1.8	0.9	0.5	0.3	0.2
0	40	1	3.2	1.5	0.9	0.9	1.0
0	40	3	3.2	1.5	0.8	0.5	0.4
0	40	6	3.2	1.6	0.8	0.5	0.2
0	40	12	3.2	1.6	0.9	0.5	0.3
1	10	1	1.4	1.0	0.8	0.7	0.5
1	10	3	0.9	0.6	0.4	0.3	0.2
1	10	6	0.8	0.5	0.3	0.2	0.1
1	10	12	0.7	0.4	0.3	0.2	0.1
1	25	1	2.5	1.8	1.2	1.0	0.9
1	25	3	2.1	1.2	0.8	0.5	0.3
1	25	6	1.9	1.1	0.6	0.4	0.2
1	25	12	1.8	1.0	0.6	0.3	0.1
1	40	1	4.0	2.6	1.8	1.4	1.3
1	40	3	3.5	2.0	1.2	0.8	0.5
1	40	6	3.3	1.8	1.0	0.6	0.3
1	40	12	3.3	1.7	1.0	0.6	0.4
8	10	1	5.0	4.4	4.2	3.6	2.8
8	10	3	2.3	1.9	1.5	1.2	0.9
8	10	6	1.6	1.2	0.9	0.7	0.5
8	10	12	1.2	0.8	0.6	0.4	0.3
8	25	1	6.5	5.4	4.6	4.1	3.2
8	25	3	3.6	2.7	2.1	1.5	1.1
8	25	6	2.8	2.0	1.4	1.0	0.7
8	25	12	2.3	1.5	1.0	0.7	0.4
8	40	1	8.3	6.6	5.3	4.5	3.6
8	40	3	5.1	3.7	2.6	1.9	1.4
8	40	6	4.3	2.8	1.9	1.3	0.8
8	40	12	3.8	2.3	1.4	1.0	0.5
15	10	1	8.6	7.7	7.1	6.5	5.1
15	10	3	3.5	3.0	2.6	2.1	1.7
15	10	6	2.2	1.8	1.5	1.2	0.9
15	10	12	1.5	1.2	0.9	0.7	0.5
15	25	1	10.1	8.7	8.2	7.0	5.4
15	25	3	4.9	4.0	3.2	2.5	1.9
15	25	6	3.5	2.6	2.0	1.5	1.1
15	25	12	2.7	1.9	1.3	1.0	0.6
15	40	1	12.1	10.1	8.6	7.6	6.0
15	40	3	6.6	5.0	3.8	2.9	2.1
15	40	6	5.0	3.6	2.5	1.9	1.3
15	40	12	4.2	2.8	1.8	1.3	0.8
30	10	1	16.2	14.7	13.6	12.7	10.0
30	10	3	6.1	5.4	4.9	4.1	3.3
30	10	6	3.5	3.0	2.6	2.1	1.6
30	10	12	2.2	1.8	1.5	1.2	0.8
30	25	1	17.8	15.8	14.5	13.2	10.3
30	25	3	7.6	6.5	5.4	4.4	3.4
30	25	6	4.9	4.0	3.2	2.5	1.8
30	25	12	3.5	2.6	2.0	1.5	1.0
30	40	1	19.8	17.2	16.3	13.8	10.7
30	40	3	9.4	7.6	6.2	4.9	3.7
30	40	6	6.6	5.0	3.8	2.9	2.1
30	40	12	5.0	3.6	2.6	1.9	1.3

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks—Continued

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
Ambient Soil Unit Weight = 15.0 kilonewton per cubic meter							
0	10	1	0.7	0.3	0.2	0.2	0.2
0	10	3	0.7	0.3	0.2	0.1	0.1
0	10	6	0.7	0.3	0.2	0.1	0.1
0	10	12	0.7	0.3	0.2	0.1	0.1
0	25	1	1.8	0.8	0.5	0.5	0.6
0	25	3	1.8	0.9	0.5	0.3	0.2
0	25	6	1.8	0.9	0.5	0.3	0.1
0	25	12	1.8	0.9	0.5	0.3	0.2
0	40	1	3.2	1.5	0.9	0.9	1.0
0	40	3	3.2	1.5	0.8	0.5	0.4
0	40	6	3.2	1.6	0.8	0.5	0.2
0	40	12	3.2	1.6	0.9	0.5	0.3
1	10	1	1.2	0.9	0.7	0.6	0.5
1	10	3	0.9	0.6	0.4	0.3	0.2
1	10	6	0.8	0.5	0.3	0.2	0.1
1	10	12	0.7	0.4	0.3	0.2	0.1
1	25	1	2.4	1.6	1.1	0.9	0.8
1	25	3	2.0	1.2	0.7	0.5	0.3
1	25	6	1.9	1.1	0.6	0.4	0.2
1	25	12	1.9	1.0	0.6	0.3	0.2
1	40	1	3.9	2.4	1.7	1.3	1.3
1	40	3	3.5	1.9	1.1	0.7	0.5
1	40	6	3.3	1.8	1.0	0.6	0.3
1	40	12	3.3	1.7	1.0	0.6	0.4
8	10	1	4.2	3.7	3.5	2.9	2.3
8	10	3	2.0	1.6	1.3	1.0	0.7
8	10	6	1.4	1.1	0.8	0.6	0.4
8	10	12	1.1	0.8	0.5	0.4	0.3
8	25	1	5.7	4.7	3.9	3.3	2.7
8	25	3	3.3	2.4	1.8	1.3	1.0
8	25	6	2.6	1.8	1.2	0.9	0.6
8	25	12	2.3	1.4	0.9	0.6	0.4
8	40	1	7.5	5.8	4.8	4.0	3.1
8	40	3	4.9	3.4	2.4	1.7	1.2
8	40	6	4.1	2.6	1.7	1.2	0.7
8	40	12	3.7	2.2	1.3	0.9	0.5
15	10	1	7.1	6.3	5.8	5.3	4.1
15	10	3	3.0	2.6	2.2	1.7	1.4
15	10	6	2.0	1.6	1.2	1.0	0.7
15	10	12	1.4	1.0	0.8	0.6	0.4
15	25	1	8.7	7.4	6.5	5.7	4.4
15	25	3	4.4	3.5	2.7	2.1	1.5
15	25	6	3.2	2.4	1.7	1.3	0.9
15	25	12	2.6	1.8	1.2	0.9	0.6
15	40	1	10.5	8.7	7.2	6.2	5.0
15	40	3	6.1	4.5	3.3	2.5	1.8
15	40	6	4.8	3.3	2.3	1.6	1.1
15	40	12	4.1	2.6	1.7	1.2	0.7
30	10	1	13.2	11.9	11.0	10.3	8.0
30	10	3	5.1	4.4	4.0	3.3	2.6
30	10	6	3.0	2.6	2.2	1.7	1.3
30	10	12	2.0	1.6	1.2	1.0	0.7
30	25	1	14.8	13.0	11.8	10.7	8.4
30	25	3	6.6	5.5	4.5	3.7	2.8
30	25	6	4.4	3.5	2.7	2.1	1.5
30	25	12	3.2	2.4	1.7	1.3	0.9
30	40	1	16.8	14.4	12.9	11.3	8.8
30	40	3	8.4	6.6	5.3	4.1	3.0
30	40	6	6.1	4.5	3.3	2.5	1.8
30	40	12	4.8	3.3	2.3	1.6	1.1

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks—Continued

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
Ambient Soil Unit Weight = 18.0 kilonewton per cubic meter							
0	10	1	0.7	0.3	0.2	0.2	0.2
0	10	3	0.7	0.3	0.2	0.1	0.1
0	10	6	0.7	0.3	0.2	0.1	0.1
0	10	12	0.7	0.3	0.2	0.1	0.1
0	25	1	1.8	0.8	0.5	0.5	0.6
0	25	3	1.8	0.9	0.5	0.3	0.2
0	25	6	1.8	0.9	0.5	0.3	0.1
0	25	12	1.8	0.9	0.5	0.3	0.2
0	40	1	3.2	1.5	0.9	0.9	1.0
0	40	3	3.2	1.5	0.8	0.5	0.4
0	40	6	3.2	1.6	0.8	0.5	0.2
0	40	12	3.2	1.6	0.9	0.5	0.3
1	10	1	1.2	0.9	0.6	0.5	0.4
1	10	3	0.9	0.6	0.4	0.3	0.2
1	10	6	0.8	0.5	0.3	0.2	0.1
1	10	12	0.7	0.4	0.2	0.2	0.1
1	25	1	2.4	1.5	1.1	0.8	0.8
1	25	3	2.0	1.2	0.7	0.4	0.3
1	25	6	1.9	1.0	0.6	0.4	0.2
1	25	12	1.9	1.0	0.6	0.3	0.2
1	40	1	3.8	2.3	1.6	1.2	1.2
1	40	3	3.5	1.9	1.1	0.7	0.5
1	40	6	3.4	1.8	1.0	0.6	0.3
1	40	12	3.3	1.7	1.0	0.6	0.4
8	10	1	3.7	3.2	2.8	2.5	1.9
8	10	3	1.8	1.5	1.1	0.9	0.7
8	10	6	1.3	1.0	0.7	0.5	0.4
8	10	12	1.0	0.7	0.5	0.4	0.2
8	25	1	5.2	4.2	3.4	2.9	2.3
8	25	3	3.1	2.2	1.6	1.2	0.8
8	25	6	2.5	1.7	1.1	0.8	0.5
8	25	12	2.2	1.3	0.9	0.6	0.3
8	40	1	6.9	5.2	4.1	3.5	2.8
8	40	3	4.7	3.1	2.1	1.6	1.1
8	40	6	4.0	2.5	1.6	1.1	0.7
8	40	12	3.6	2.1	1.3	0.8	0.5
15	10	1	6.1	5.4	4.9	4.4	3.5
15	10	3	2.7	2.2	1.9	1.5	1.1
15	10	6	1.8	1.4	1.1	0.8	0.6
15	10	12	1.3	0.9	0.7	0.5	0.3
15	25	1	7.7	6.4	5.6	4.9	3.9
15	25	3	4.1	3.1	2.4	1.8	1.3
15	25	6	3.0	2.2	1.6	1.1	0.8
15	25	12	2.5	1.6	1.1	0.8	0.5
15	40	1	9.5	7.7	6.2	5.4	4.3
15	40	3	5.7	4.1	3.0	2.2	1.6
15	40	6	4.6	3.1	2.1	1.5	1.0
15	40	12	4.0	2.5	1.6	1.1	0.6
30	10	1	11.2	10.1	9.3	8.6	6.7
30	10	3	4.4	3.8	3.4	2.8	2.2
30	10	6	2.7	2.2	1.9	1.5	1.1
30	10	12	1.8	1.4	1.1	0.8	0.6
30	25	1	12.8	11.2	10.6	9.1	7.1
30	25	3	5.9	4.8	3.9	3.1	2.4
30	25	6	4.1	3.1	2.4	1.8	1.3
30	25	12	3.0	2.2	1.6	1.1	0.8
30	40	1	14.9	12.5	11.0	9.7	7.6
30	40	3	7.7	6.0	4.6	3.6	2.6
30	40	6	5.7	4.1	3.0	2.2	1.6
30	40	12	4.6	3.1	2.1	1.5	1.0

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks—Continued

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
Ambient Soil Unit Weight = 20.0 kilonewton per cubic meter							
0	10	1	0.7	0.3	0.2	0.2	0.2
0	10	3	0.7	0.3	0.2	0.1	0.1
0	10	6	0.7	0.3	0.2	0.1	0.1
0	10	12	0.7	0.3	0.2	0.1	0.1
0	25	1	1.8	0.8	0.5	0.5	0.6
0	25	3	1.8	0.9	0.5	0.3	0.2
0	25	6	1.8	0.9	0.5	0.3	0.1
0	25	12	1.8	0.9	0.5	0.3	0.2
0	40	1	3.2	1.5	0.9	0.9	1.0
0	40	3	3.2	1.5	0.8	0.5	0.4
0	40	6	3.2	1.6	0.8	0.5	0.2
0	40	12	3.2	1.6	0.9	0.5	0.3
1	10	1	1.1	0.9	0.6	0.5	0.4
1	10	3	0.8	0.5	0.3	0.2	0.2
1	10	6	0.8	0.5	0.3	0.2	0.1
1	10	12	0.7	0.4	0.2	0.1	0.1
1	25	1	2.3	1.5	1.0	0.8	0.8
1	25	3	11.6	1.1	0.7	0.4	0.3
1	25	6	1.9	1.0	0.6	0.4	0.2
1	25	12	1.8	1.0	0.6	0.3	0.2
1	40	1	3.7	2.2	1.5	1.2	1.2
1	40	3	3.4	1.8	1.1	0.7	0.5
1	40	6	3.3	1.8	1.0	0.6	0.3
1	40	12	3.2	1.7	1.0	0.5	0.4
8	10	1	3.4	2.9	2.6	2.3	1.8
8	10	3	1.7	1.3	1.1	0.8	0.6
8	10	6	1.2	0.9	0.7	0.5	0.3
8	10	12	1.0	0.7	0.5	0.3	0.2
8	25	1	4.8	3.9	3.1	2.6	2.1
8	25	3	2.9	2.1	1.5	1.1	0.8
8	25	6	2.4	1.6	1.1	0.8	0.5
8	25	12	2.1	1.3	0.8	0.6	0.3
8	40	1	6.4	4.9	3.8	3.3	2.6
8	40	3	4.4	3.0	2.1	1.5	1.0
8	40	6	3.9	2.4	1.5	1.0	0.6
8	40	12	3.5	2.1	1.2	0.8	0.4
15	10	1	5.5	4.9	4.3	4.0	3.1
15	10	3	2.5	2.1	1.7	1.3	1.0
15	10	6	1.6	1.3	1.0	0.8	0.5
15	10	12	1.2	0.9	0.7	0.5	0.3
15	25	1	7.0	5.9	5.1	4.5	3.5
15	25	3	3.8	2.9	2.2	1.7	1.2
15	25	6	2.9	2.1	1.5	1.1	0.7
15	25	12	2.4	1.6	1.1	0.7	0.5
15	40	1	8.8	7.1	5.8	4.9	4.0
15	40	3	5.4	3.9	2.8	2.1	1.5
15	40	6	4.4	2.9	2.0	1.4	0.9
15	40	12	3.8	2.4	1.5	1.0	0.6
30	10	1	10.1	9.1	8.2	7.8	6.1
30	10	3	4.0	3.5	3.0	2.4	1.8
30	10	6	2.5	2.1	1.7	1.3	0.9
30	10	12	1.6	1.3	1.0	0.8	0.5
30	25	1	11.7	10.2	9.7	8.2	6.4
30	25	3	5.5	4.5	3.6	2.8	2.0
30	25	6	3.8	2.9	2.2	1.6	1.1
30	25	12	2.9	2.1	1.5	1.1	0.7
30	40	1	13.6	11.5	10.1	8.8	7.0
30	40	3	7.2	5.6	4.3	3.3	2.4
30	40	6	5.4	3.9	2.8	2.0	1.4
30	40	12	4.4	2.9	2.0	1.4	0.9

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks—Continued

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
			Saturated Soil Unit Weight = 15.0 kilonewton per cubic meter				
0	10	1	0.2	0.1	0.1	0.1	0.1
0	10	3	0.2	0.1	0.1	0.1	0.1
0	10	6	0.2	0.1	0.1	0.1	0.1
0	10	12	0.2	0.1	0.1	0.1	0.1
0	25	1	0.6	0.2	0.1	0.1	0.1
0	25	3	0.6	0.2	0.1	0.1	0.1
0	25	6	0.6	0.2	0.1	0.1	0.1
0	25	12	0.6	0.2	0.1	0.1	0.1
0	40	1	1.1	0.3	0.1	0.1	0.1
0	40	3	1.2	0.3	0.1	0.1	0.1
0	40	6	1.2	0.3	0.1	0.1	0.1
0	40	12	1.1	0.3	0.1	0.1	0.1
1	10	1	0.8	0.6	0.4	0.3	0.2
1	10	3	0.5	0.3	0.1	0.1	0.1
1	10	6	0.4	0.2	0.1	0.1	0.1
1	10	12	0.3	0.1	0.1	0.1	0.1
1	25	1	1.3	0.8	0.4	0.3	0.2
1	25	3	0.9	0.4	0.1	0.1	0.1
1	25	6	0.8	0.3	0.1	0.1	0.1
1	25	12	0.7	0.3	0.1	0.1	0.1
1	40	1	2.0	1.0	0.5	0.3	0.2
1	40	3	1.5	0.6	0.1	0.1	0.1
1	40	6	1.3	0.5	0.1	0.1	0.1
1	40	12	1.2	0.4	0.1	0.1	0.1
8	10	1	3.6	3.1	2.7	2.3	2.0
8	10	3	1.5	1.2	0.9	0.7	0.5
8	10	6	1.0	0.7	0.5	0.3	0.1
8	10	12	0.7	0.4	0.3	0.1	0.1
8	25	1	4.4	3.6	3.0	2.5	2.0
8	25	3	2.2	1.5	1.0	0.6	0.2
8	25	6	1.5	1.0	0.6	0.2	0.1
8	25	12	1.2	0.6	0.3	0.1	0.1
8	40	1	5.3	4.0	3.1	2.6	1.9
8	40	3	2.9	1.8	1.1	0.5	0.1
8	40	6	2.2	1.2	0.6	0.1	0.1
8	40	12	1.7	0.8	0.3	0.1	0.1
15	10	1	6.2	5.6	5.1	4.6	3.7
15	10	3	2.4	2.1	1.7	1.4	1.0
15	10	6	1.4	1.2	0.9	0.7	0.4
15	10	12	0.9	0.7	0.5	0.3	0.1
15	25	1	7.1	6.1	5.2	4.6	3.7
15	25	3	3.2	2.4	1.8	1.3	0.8
15	25	6	2.1	1.4	1.0	0.6	0.1
15	25	12	1.5	0.9	0.5	0.2	0.1
15	40	1	8.1	6.7	5.5	4.7	3.7
15	40	3	4.0	2.8	2.0	1.2	0.3
15	40	6	2.8	1.7	1.1	0.5	0.1
15	40	12	2.1	1.2	0.6	0.1	0.1
30	10	1	11.7	10.7	10.1	9.1	7.4
30	10	3	4.3	3.8	3.4	2.8	2.2
30	10	6	2.4	2.1	1.7	1.4	1.0
30	10	12	1.4	1.2	0.9	0.7	0.4
30	25	1	12.7	11.4	10.3	9.1	7.4
30	25	3	5.2	4.3	3.5	2.8	1.9
30	25	6	3.2	2.4	1.8	1.3	0.7
30	25	12	2.1	1.4	1.0	0.6	0.1
30	40	1	13.9	12.1	10.4	9.2	7.4
30	40	3	6.1	4.8	3.6	2.7	1.6
30	40	6	4.0	2.8	1.9	1.2	0.1
30	40	12	2.8	1.7	1.1	0.5	0.1

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks—Continued

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
Saturated Soil Unit Weight = 18.0 kilonewton per cubic meter							
0	10	1	0.3	0.1	0.1	0.1	0.1
0	10	3	0.3	0.1	0.1	0.1	0.1
0	10	6	0.3	0.1	0.1	0.1	0.1
0	10	12	0.3	0.1	0.1	0.1	0.1
0	25	1	0.8	0.2	0.1	0.1	0.1
0	25	3	0.8	0.2	0.1	0.1	0.1
0	25	6	0.8	0.3	0.1	0.1	0.1
0	25	12	0.8	0.3	0.1	0.1	0.1
0	40	1	1.4	0.4	0.1	0.1	0.1
0	40	3	1.4	0.4	0.1	0.1	0.1
0	40	6	1.4	0.5	0.1	0.1	0.1
0	40	12	1.3	0.5	0.1	0.1	0.1
1	10	1	0.8	0.6	0.4	0.3	0.2
1	10	3	0.5	0.3	0.2	0.1	0.1
1	10	6	0.4	0.2	0.1	0.1	0.1
1	10	12	0.4	0.2	0.1	0.1	0.1
1	25	1	1.4	0.8	0.5	0.4	0.3
1	25	3	1.1	0.5	0.2	0.1	0.1
1	25	6	0.9	0.4	0.1	0.1	0.1
1	25	12	0.9	0.3	0.1	0.1	0.1
1	40	1	2.1	1.1	0.6	0.4	0.3
1	40	3	1.7	0.7	0.2	0.1	0.1
1	40	6	1.6	0.6	0.1	0.1	0.1
1	40	12	1.5	0.6	0.1	0.1	0.1
8	10	1	3.3	2.9	2.4	2.1	1.8
8	10	3	1.5	1.2	0.9	0.6	0.4
8	10	6	1.0	0.7	0.5	0.3	0.1
8	10	12	0.7	0.4	0.3	0.1	0.1
8	25	1	4.3	3.4	2.7	2.3	1.8
8	25	3	2.2	1.5	1.0	0.6	0.2
8	25	6	1.6	1.0	0.6	0.2	0.1
8	25	12	1.3	0.7	0.3	0.1	0.1
8	40	1	5.3	3.9	2.9	2.5	1.8
8	40	3	3.0	1.9	1.1	0.5	0.1
8	40	6	2.3	1.3	0.6	0.1	0.1
8	40	12	1.9	0.9	0.3	0.1	0.1
15	10	1	5.6	5.1	4.6	4.1	3.3
15	10	3	2.3	1.9	1.6	1.3	0.9
15	10	6	1.4	1.1	0.8	0.6	0.4
15	10	12	0.9	0.7	0.5	0.3	0.1
15	25	1	6.7	5.7	4.7	4.2	3.3
15	25	3	3.1	2.3	1.7	1.2	0.7
15	25	6	2.1	1.4	1.0	0.6	0.1
15	25	12	1.6	0.9	0.5	0.2	0.1
15	40	1	7.8	6.3	5.1	4.3	3.4
15	40	3	4.0	2.8	1.9	1.2	0.4
15	40	6	2.9	1.8	1.1	0.5	0.1
15	40	12	2.3	1.2	0.6	0.1	0.1
30	10	1	10.6	9.7	9.1	8.1	6.6
30	10	3	4.0	3.5	3.1	2.5	2.0
30	10	6	2.3	1.9	1.6	1.2	0.9
30	10	12	1.4	1.1	0.8	0.6	0.3
30	25	1	11.7	10.4	9.2	8.2	6.7
30	25	3	5.0	4.1	3.2	2.5	1.8
30	25	6	3.1	2.3	1.7	1.2	0.7
30	25	12	2.1	1.4	1.0	0.6	0.1
30	40	1	13.1	11.2	9.5	8.3	6.7
30	40	3	6.0	4.6	3.4	2.5	1.5
30	40	6	4.0	2.8	1.9	1.2	0.1
30	40	12	2.9	1.8	1.1	0.5	0.1

Table 6. Factors of safety from Rotational Equilibrium Analysis of Multilayered Embankments (REAME) analysis of idealized straight banks—Continued

[kPa, kilopascal; °, degrees; m, meter]

Cohesion (kPa)	Friction angle (°)	Bank height (m)	Bank angle				
			15°	30°	50°	70°	90°
Saturated Soil Unit Weight = 20.0 kilonewton per cubic meter							
0	10	1	0.3	0.1	0.1	0.1	0.1
0	10	3	0.3	0.1	0.1	0.1	0.1
0	10	6	0.3	0.1	0.1	0.1	0.1
0	10	12	0.3	0.1	0.1	0.1	0.1
0	25	1	0.9	0.3	0.1	0.1	0.1
0	25	3	0.9	0.3	0.1	0.1	0.1
0	25	6	0.9	0.3	0.1	0.1	0.1
0	25	12	0.9	0.3	0.1	0.1	0.1
0	40	1	1.5	0.6	0.2	0.1	0.2
0	40	3	1.6	0.6	0.1	0.1	0.1
0	40	6	1.6	0.5	0.1	0.1	0.1
0	40	12	1.5	0.6	0.1	0.1	0.1
1	10	1	0.8	0.6	0.4	0.3	0.2
1	10	3	0.5	0.3	0.2	0.1	0.1
1	10	6	0.5	0.2	0.1	0.1	0.1
1	10	12	0.4	0.2	0.1	0.1	0.1
1	25	1	1.5	0.9	0.5	0.4	0.3
1	25	3	1.1	0.5	0.2	0.1	0.1
1	25	6	1.0	0.5	0.1	0.1	0.1
1	25	12	1.0	0.4	0.1	0.1	0.1
1	40	1	2.3	1.2	0.6	0.3	0.4
1	40	3	1.9	0.8	0.2	0.1	0.1
1	40	6	1.7	0.7	0.1	0.1	0.1
1	40	12	1.6	0.7	0.1	0.1	0.1
8	10	1	3.1	2.7	2.2	1.9	1.6
8	10	3	1.4	1.1	0.8	0.6	0.4
8	10	6	1.0	0.7	0.5	0.3	0.1
8	10	12	0.7	0.4	0.3	0.1	0.1
8	25	1	4.1	3.2	2.5	2.2	1.7
8	25	3	2.2	1.5	1.0	0.6	0.2
8	25	6	1.7	1.0	0.6	0.3	0.1
8	25	12	1.3	0.7	0.3	0.1	0.1
8	40	1	5.2	3.7	2.7	2.4	1.7
8	40	3	3.1	1.9	1.1	0.5	0.1
8	40	6	2.5	1.3	0.7	0.1	0.1
8	40	12	2.1	1.0	0.4	0.1	0.1
15	10	1	5.2	4.7	4.2	3.7	3.0
15	10	3	2.2	1.8	1.5	1.2	0.8
15	10	6	1.4	1.0	0.8	0.6	0.3
15	10	12	0.9	0.6	0.4	0.3	0.1
15	25	1	6.4	5.3	4.4	3.8	3.1
15	25	3	3.1	2.3	1.7	1.2	0.7
15	25	6	2.2	1.4	0.9	0.6	0.1
15	25	12	1.6	1.0	0.6	0.2	0.1
15	40	1	7.7	5.9	4.7	4.0	3.1
15	40	3	4.1	2.7	1.9	1.2	0.5
15	40	6	3.0	1.8	1.1	0.5	0.1
15	40	12	2.4	1.3	0.6	0.1	0.1
30	10	1	9.7	8.8	8.2	7.3	6.0
30	10	3	3.7	3.3	2.8	2.3	1.8
30	10	6	2.2	1.8	1.5	1.1	0.8
30	10	12	1.4	1.0	0.8	0.6	0.3
30	25	1	11.0	9.6	8.7	7.5	6.0
30	25	3	4.8	3.8	3.0	2.3	1.6
30	25	6	3.1	2.3	1.6	1.2	0.6
30	25	12	2.2	1.4	0.9	0.6	0.1
30	40	1	12.4	10.4	8.7	7.6	6.1
30	40	3	5.9	4.4	3.2	2.3	1.4
30	40	6	4.1	2.7	1.8	1.2	0.1
30	40	12	3.0	1.8	1.1	0.5	0.1

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