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Section 3

Sedimentation

Chapter 5

Deposition of Sediment

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Chapter 5
Deposition of Sediment

General

This chapter describes various types of sediment deposits and the physical damage they cause.[1] SCS geologists identify many types of sediment deposits, determine their rates of deposition, and compare these rates with natural or geologic rates of deposition. Such investigations are concerned chiefly with sediment deposits on flood plains and in channels and reservoirs. The deposits are discussed in the general sequence in which they occur from the uplands to the sea.

Kinds of physical damage commonly caused by sediment deposition are:

1. Burial of fertile soils by less fertile sediment.
2. Damage to growing crops and burial of crops.
3. Impairment of drainage and the accompanying rise of the water table and increase in swampy areas of alluvial land.
4. Filling of channels, causing more frequent flooding and increased flood heights. Filling may change the course of the channel.
5. Filling of reservoirs and debris basins.
6. Damage to railroads, bridges, roads, powerlines, and other facilities. Ditches and roads may be filled enough to need regrading.
7. Damage to urban areas from sedimentation and increased flood heights.
8. Damage to recreation facilities.

The extent of the damages is ordinarily calculated in terms of the degree of possible restoration to original conditions or the extent of the loss of productivity or services. Geologists and economists work closely together to determine the damage. Geologists obtain information on the physical damage and economists figure the costs on the basis of this information.

Occurrence

A typical alluvial fan is an accumulation of sediment carried by a stream descending through a steep ravine or canyon. When the stream emerges from this confined area, it loses velocity and drops most of the sediment, which spreads out in the shape of a fan. The fan is roughly semiconical, with the apex at the canyon end. The materials composing an alluvial fan range in size from fines to boulders. The streams supplying debris to fans are agents of vigorous erosion, and they commonly transport an enormous volume of sediment. Boulders, cobbles, and gravel are deposited at the upper end of a fan, and the finer sands, silts, and clays are carried to lower elevations (fig. 5–1).

Much of the stream water percolates through the porous coarse material in the fan. The spreading of streamflow and the loss of water through percolation cause deposition of the entire sediment load. The steepness and size of alluvial fans vary with the geology, climate, and watershed size. Fan deposits range from wide fans of moderate slope (4 to 6 degrees) to relatively steep cones (as much as 15 degrees) built of coarse debris transported by short torrential streams (Holmes 1965).

Streams on a fan characteristically change course frequently and develop a series of distributaries. Fans may be isolated or they may coalesce to form a long, broad alluvial slope. The development of many fans is characterized by erratic and sudden depositional events, especially in arid and semiarid climates. Long periods of quiescence may be ended by heavy rains producing torrential flows. The volume of sediment deposited on fan areas below mountain slopes and canyons after a single heavy rain can be enormous. Deposits along mountain fronts in the United States are important because many of them are in agricultural or urban areas and are present difficult problems.

Damage caused by sediment-laden flows ranges from disasters following severe storms to relatively minor incidents following more frequent smaller storms. Many fans are forming at the foot of valley slopes in the Central Lowlands and even in the rougher parts of the Coastal Plains.

Identification

Fan deposition is not limited to mountain environments. The composition of all fan deposits closely resembles that of the parent rock, since relatively little chemical weathering has taken place. The coarse-textured sediment ranges from angular to round, depending on the distance moved and the resistance of the rock to abrasion. The coarser sediment of a fan is deposited near the top (apex) of the fan, where the slope is usually steepest. Near the base of the fan, where the slope decreases, the grain size also decreases. Bedding is not distinct or regular, however, in fan deposits.

Procedures for Determining Physical Damage

The study of damage caused by fan deposition should begin with preparation of a map showing the area affected. The map should show the chief features of concern (drainage, topography, and sediment sources), and the fan areas should be drawn to scale.

A survey to determine the volume, texture, and depth of the deposit will yield measurements of the fan and its associated damages. The survey can be coordinated with a system of ranges to obtain cross sections of the valley. The ranges in the fan area should be spaced closely enough to show more detail. Borings along the cross sections or ranges can help identify possible buried old soil horizons, although borings may not provide conclusive information at many points in the fan. The great thickness and coarseness of many fans may make measurements by boring impractical. For data on annual damages and volume of deposition, the investigation should be supported by the best historical records obtainable.

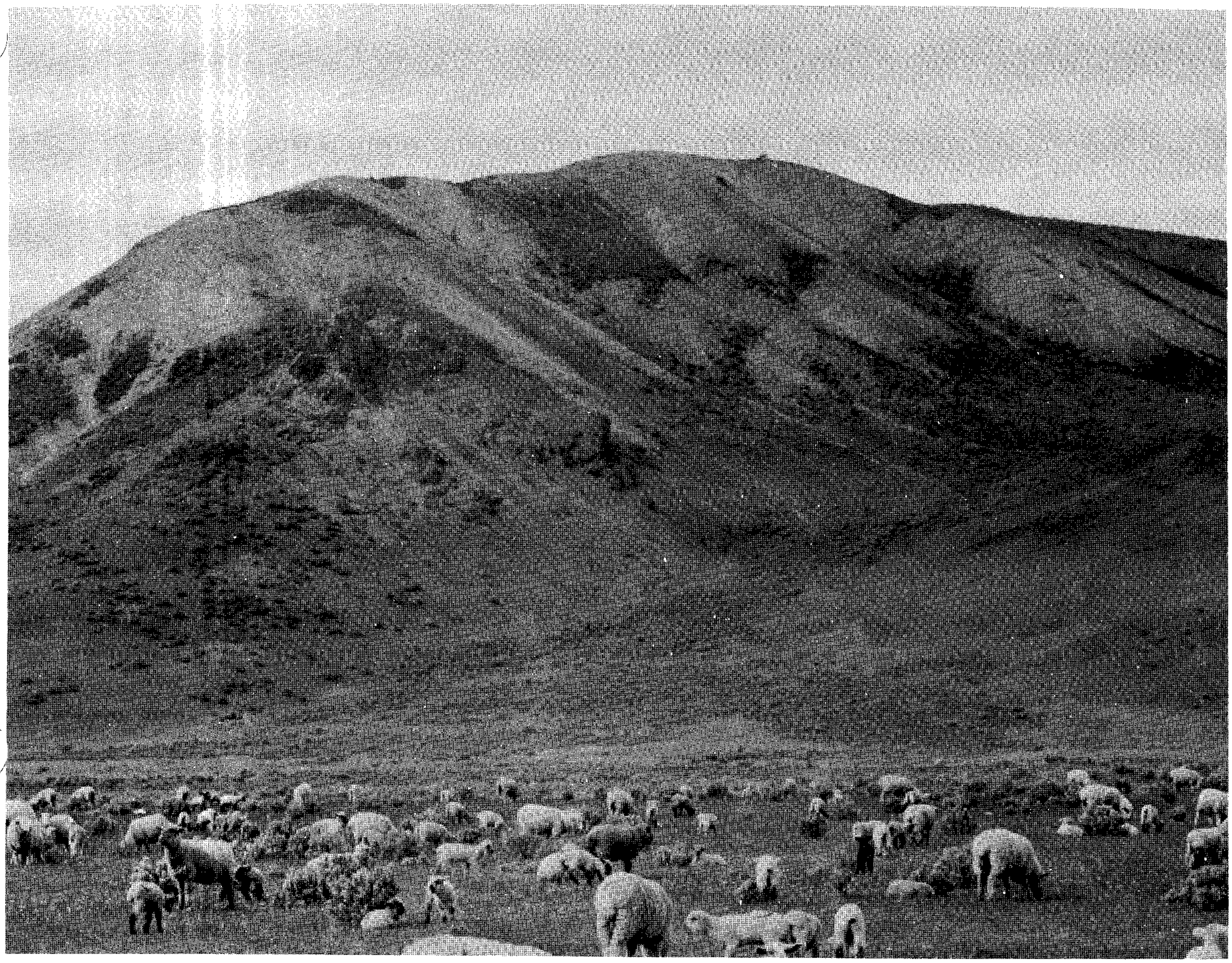

Figure 5–1.—An alluvial fan, Okanogan County, Wash.

Colluvial Deposition

Colluvial deposits are products of upland erosion that are moved by gravity, mass movement, or unconcentrated surface runoff; they commonly accumulate on the lower part or base of slopes. They represent some of the products of erosion that do not reach stream channels, reservoirs, or other points where sediment quantity and movement usually are measured. Colluvial deposits tend to accumulate where upland slopes decrease, which may be at the foot of a slope or wherever the transporting power of the overland flow is lessened. Upland colluvial deposition is thus closely related to sheet erosion. Colluvial deposits characteristically are narrow bands of sediment deposits having linear or sinuous shape. A reasonably complete survey of an area provides information on the approximate volume of colluvial deposits. This volume can then be subtracted from the calculated total erosion to determine sediment yield to an area farther downstream. The history of land use and cultivation in the area can provide a basis for calculating the annual contribution to the colluvial deposits.

The extent of damage caused by colluvial deposits varies widely. The basis of all damage estimates should be:

1. A map showing the extent of the area.
2. Borings for volume and rate of deposition, supported by local history.
3. Determination of the nature of the sediment and its effects.

Flood-Plain Deposition

Occurrence

A flood plain is a strip of relatively smooth land that borders a stream and is covered with water when the stream overflows (Leopold, Wolman, and Miller 1964). Flood plains range from a few feet to several miles wide.

In a valley where modern sedimentation is widespread, the natural levees, which in many places are dominant features, may be several feet thick. Away from the channel and natural levees the vertical-accretion deposits generally decrease in thickness toward the edges of the flood plain.

Where sedimentation from tributaries and valley slopes has been rapid, alluvial fans and colluvial deposits overlap the edges of the flood-plain deposits. If deposition in the main channel has been excessive, the channel may have become filled and its bottom elevation may be higher than the surrounding flood plain. Subsequent flood flows may then follow an entirely different course. In some valleys, modern sedimentation has substantially damaged the flood plain but has not formed a continuous valley-wide deposit.

The following descriptions of flood-plain deposits are after Happ, Rittenhouse, and Dobson (1940).

Vertical-Accretion Deposits

In times of flood, stream channels lack the capacity to carry all the water delivered to them as surface runoff. The excess water overflows the banks and spreads over the adjacent flood plain. Because of greater frictional resistance, this spreading markedly reduces velocity and reduces transporting capacity even more. Part of the sediment that was carried in suspension while the water was confined to the channel is therefore deposited on the flood plain. As velocity decreases, the coarse material is dropped first and builds up the characteristically sandy natural levees that border the channels. The finer sediment is carried farther from the channel and deposited as a thin layer over the entire flood-plain surface. This is the process of vertical accretion, and the deposits are composed almost entirely of sediment carried to the place of deposition as suspended load. In this respect vertical-accretion deposits differ from channel deposits, which are largely composed of bedload sediment (fig. 5–2).

Flood-Plain Splays

The regularity of flood-plain deposition is interrupted where excess water leaves the channel through restricted low sections or breaks in the natural levees. In such places the velocity of the escaping water may be high enough to carry an appreciable amount of relatively coarse sediment farther from the channel than would otherwise happen. The sand and gravel sediment is commonly spread outward in a fan shape on the flood plain, across which it is moved forward at least partly as bedload. The resulting deposits are flood-plain splays.

Other Deposits

Colluvial deposits occur on flood-plain borders at the base of slopes. They are composed of material moved by gravity, mass movement, and sheet erosion.

Older channel deposits underlie much of the flood plain. Channel-fill deposits, lateral-accretion deposits, and valley-plug deposits are described under channel deposition.

Identification

Identifying deposits formed by modern accelerated deposition depends chiefly on the ability to distinguish between modern sediment and the buried original flood-plain soil. Since the characteristics of both the sediment and the buried soils may differ in different valleys, their relationships must be investigated when beginning a valley survey. The important criteria for differentiating modern sediment from buried soil are as follows:

Texture

Modern sediment is usually coarser and varies more in texture than buried soil.

Color

Modern sediment is usually a light color that may vary with texture; buried soil is usually darker and more uniform in both color and texture. Modern sediments may have a gray or greenish-gray staining as a result of a formerly high ground-water table.

Compaction

Modern sediment is often less compact and less cohesive than buried soil.

Distinctive Minerals

Modern sediment may contain grains of gypsum, feldspars, calcite, or other easily weathered minerals. Very few grains of easily weathered minerals occur in buried soil. Buried soil usually contains more clay minerals than modern sediment.

Evidence of Cultural Activity

Modern sediment may cover or contain boards, tools, bricks, fences, other manmade objects, and tree stumps.

Stratification

In many places modern sediment has distinct stratification with crossbedding and lenticular beds.

Procedures for Determining the Extent of Deposition

A survey of a watershed area should include a study of all important valleys. Information bearing on erosion rates, sediment yield, and flooding should be summarized. Summaries should include valley width and depth, nature of the slopes, chief rock outcrops, nature and extent of terraces and their relationships to channels. These features all directly influence the nature and magnitude of the sediment deposits (Roehl and Holeman 1975).

Figure 5–2.—Vertical accretion, subsoil over topsoil in creek bottom, Fairfield County, Ohio.

Occurrence

Sediment is deposited in channels in many situations and environments, including alluvial fans, large river valleys, distributaries and passes of deltas, and alluvial plains. Deposits resulting from channel fill and lateral accretion can be found throughout any flood plain (fig. 5–3).

Identification

An accumulation of sediment in a channel results from the inability of the stream to carry all its load. The process of accumulation has been described by Happ, Rittenhouse, and Dobson (1940); Brown (1950); Einstein (1950); Leopold, Wolman, and Miller (1964); Happ (1975); and others. Generally, the coarsest sediment is deposited in and along the channel. The channel may be partly or completely filled, so that future flows follow an entirely different course. Channel deposits can be identified by their coarse texture and sinuous shape and by the damage caused, such as filled channelways and bridge openings and new areas of swamping.

Channel-Fill Deposits

These deposits occur in stream channels where the transporting capacity has been insufficient to remove the sediment as rapidly as it has been delivered. The process is not a simple sorting out and deposition of the coarsest material but consists of a net accumulation of material from alternating scour (during rising flood stages) and deposition (during the falling stages). If the average amount of scour is less than the average amount of deposition, the net result is aggradation of the channel bed. Channel deposits are generally coarse textured (fig. 5–4).

Valley-Plug Deposits

These deposits are always associated with filling of the stream channel. When the channel has been completely filled in one place, the area of deposition moves upstream by backfilling. At the same time, the water flowing in the channel is forced overbank, draining down the valley as through back-swamp areas, until it again collects into definite channels and eventually returns to the main channel.

Plugs are caused by a decrease in the transport capacity of the stream channel. The channel capacity can be decreased by fallen trees and jams of driftwood, by delivery of sediment from a tributary in quantities that completely choke the main stream channel, or by inadequate artificial channel modification downstream. The cause of the original channel obstruction may not be evident.

Lateral-Accretion Deposits

These deposits form along the sides of channels, where bedload material is moved by traction toward the inner sides of channel bends. Normally, such deposits of lateral accretion are later covered by finer material of vertical accretion as the channel shifts farther away from its former course by lateral bank cutting. The old slip-off slope on the inside of the bend then is overflowed less frequently and with lower velocity.

Procedure for Determining Physical Damage

The quantity of and damage from channel deposits should be measured by borings to determine thickness, by mapping to determine extent, and by reviewing the most recent records available to determine frequency of deposition. Information on clearing of sediment from channels and under bridges, as well as from road surfaces, is often available in county engineers' offices and can be used as one measure of the damage caused by channel action. The information gathered may include:

1. Volume of channel and bridge clearing.
2. Depth and area of places where channel action has raised the water table.
3. Amount of increase in the flood hazard and damage, which can be investigated and evaluated along the ranges of the watershed survey.

Association of Flood-Plain and Channel Deposits

In the normal flood-plain association of sediments, vertical-accretion deposits cover coarse lateral-accretion and channel-fill deposits. Vertical-accretion deposits cover the flood plain with a layer of fine sediment fairly uniform in thickness that slopes away from the channel to the valley sides. Vertical-accretion deposits are the chief sources of

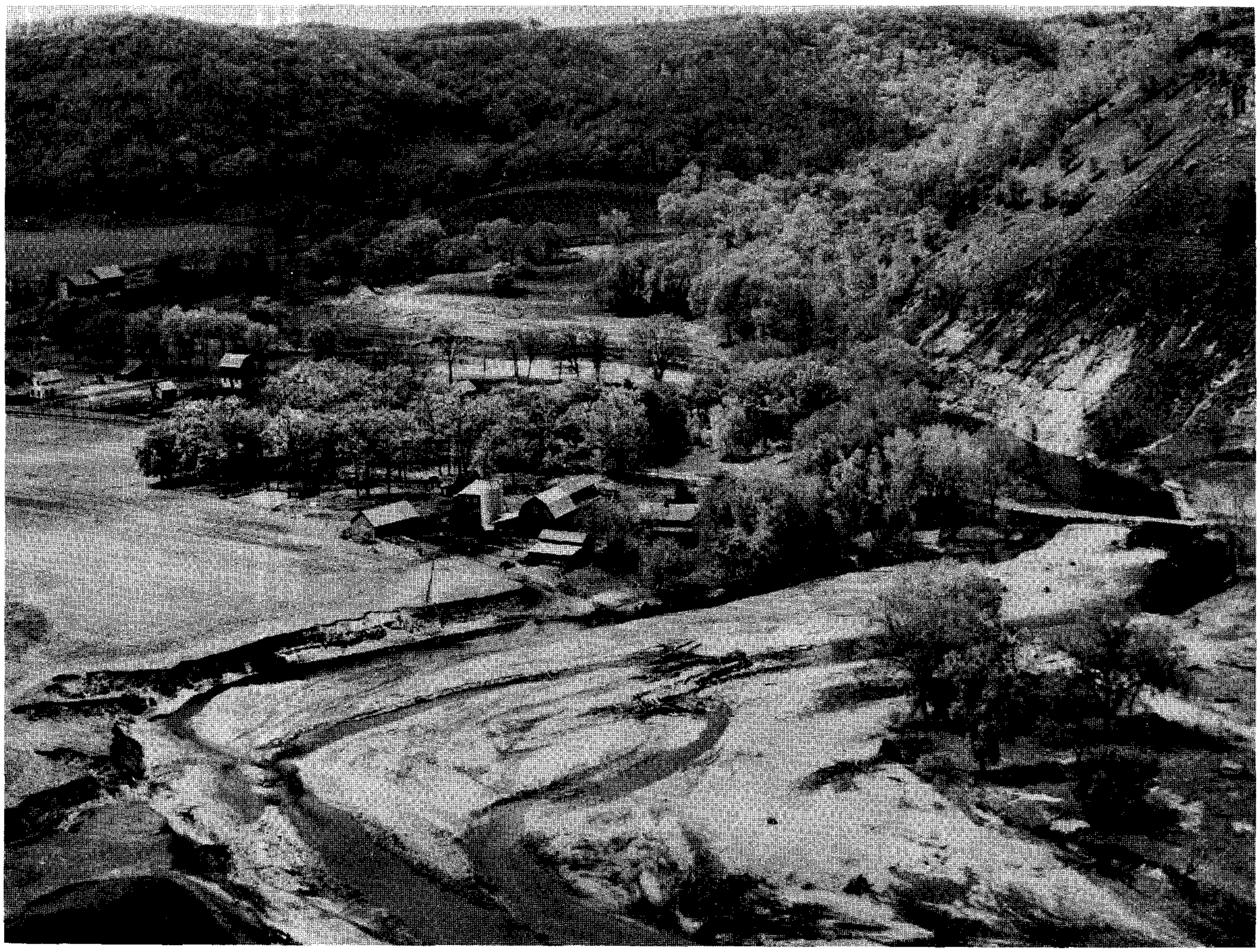

Figure 5–3.—Channel fill, lateral and vertical accretion, Winona County, Minn.

the fertile bottom land in most valleys.

Modern channel-fill deposits occur in the present channel and in abandoned channels. They may be covered by vertical-accretion deposits in the abandoned channels. Sand splays occur immediately alongside present or former channels and interfinger into the vertical-accretion deposits. Colluvial and fan deposits interfinger into the vertical-accretion deposits from the valley sides. The characteristically low area between the natural levees and the colluvial deposits is called the backswamp part of the flood plain. Characteristics of the different types of deposits in the normal flood-plain association are summarized in table 5–1.

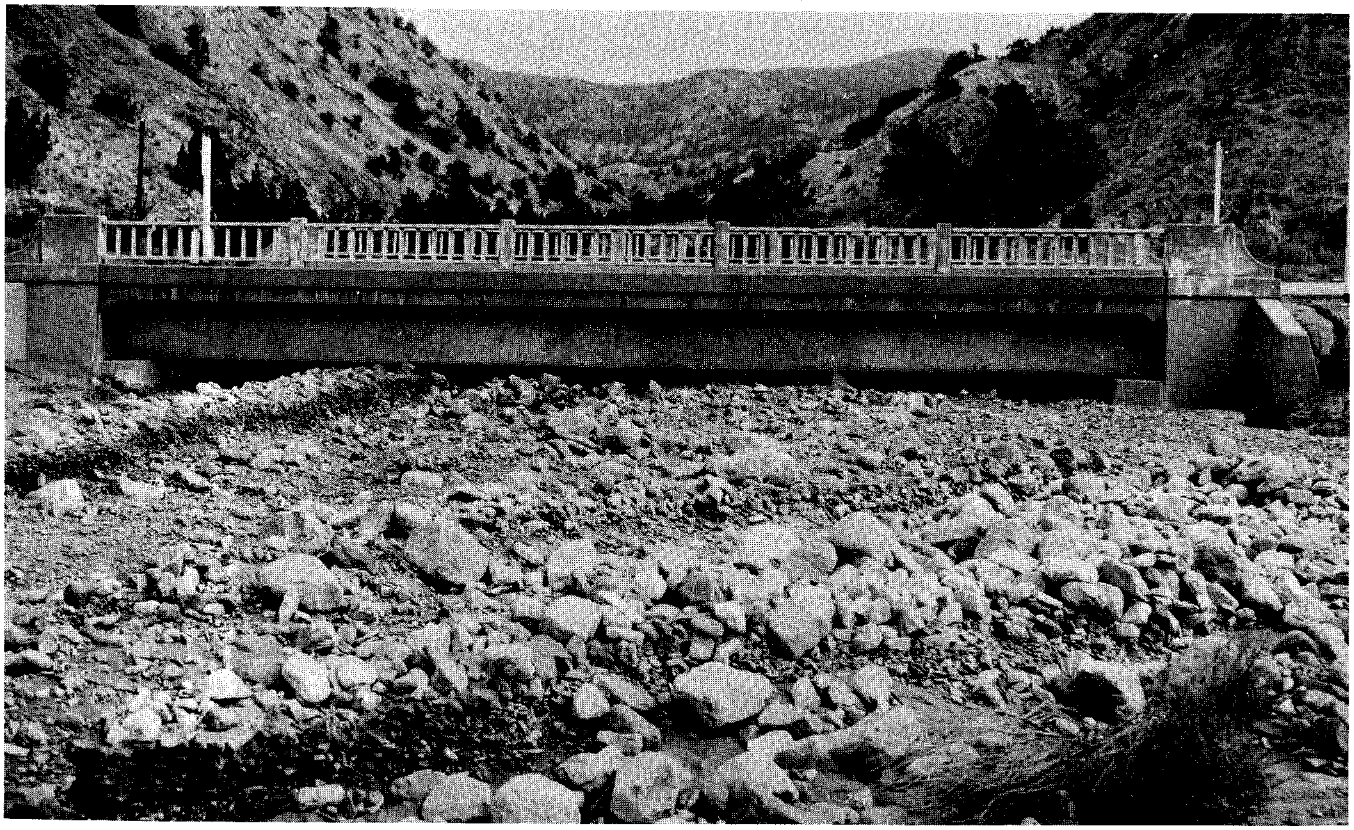

Figure 5–4.—Coarse channel fill, Salt Creek, Iron County, Utah.

Table 5–1.—Characteristics of genetic types of valley deposits

Characteristic	Colluvial deposits	Fluvial deposits: Vertical accretion	Fluvial deposits: Splays	Fluvial deposits: Lateral accretion	Fluvial deposits: Channel fill
Principal origin	Concentration by slope wash and mass movements	Deposition of suspended load	Deposition of bedload	Deposition of bedload always prominent, but suspended load may be dominant	Deposition of bedload and suspended load
Usual place of deposit	At junction of flood plain and valley sides	On entire flood-plain surface	On flood-plain surface adjacent to stream channel	Along side of channel, especially on the inside of bends	Within the channel
Dominant texture	Range from silty clay to boulders	Dominantly silt; often sandy, especially near channel; often much clay	Usually sand; may be gravel or boulders	Sand or gravel; may include silt or boulders	Usually sand, silt, and gravel; may include clay or boulders
Relative distribution in the valley fill	Interfinger with the fluvial deposits along outer margins of flood plain	Overlie lateral accretion and channel deposits; overlain by or interbedded with splay and colluvial deposits; usually cover most of flood-plain surface	Form scattered lenticular deposits overlying or interbedded with vertical accretion deposits adjacent to present or former channels	Usually underlie vertical-accretion deposits, often overlie channel-fill deposits; may extend across entire flood-plain width	Usually form elongate deposits of relatively small cross section winding through flood plain; may underlie vertical-accretion deposits

Only a general description of sediment deposits in artificial basins is presented in this chapter. Additional details on reservoir sedimentation are given by many investigators, including Stevens (1936); Eakin (1939); Noll, Roehl, and Bennett (1950); Holeman and Geiger (1959); and Gottschalk (1975). Methods for measuring and evaluating sedimentation in reservoirs are discussed in other parts of this section, including Chapter 6, Sediment Sources, Yields, and Delivery Ratios; and Chapter 7, Field Investigations and Surveys.

Character and Distribution

Sediments deposited in impounding reservoirs designed to keep fluctuations in the water level to a minimum have a typical texture and distribution. The bulk of the deposit consists of clay and silt particles distributed fairly evenly over the reservoir bottom. The coarser particles (sand, gravel, and boulders) are deposited in or near the head of the impounded pool, where the velocity of inflowing currents is reduced. The silt and clay particles remain in suspension longer and are spread widely over the reservoir bottom. Some sands, gravels, and poorly sorted deposits may occur in relatively narrow shore zones, especially if wave erosion has been active. The composition and texture of beach deposits depend on the nature of the shore (Jones and Roger 1952; Jones, Renfro, and Commons 1954).

If the water level in a reservoir fluctuates widely, the character and distribution of the sediment deposit change considerably. When a large withdrawal of water coincides with a period of drought, the water in the pool may fall to a very low level or the reservoir may be completely drained. When exposed to air, the clay and silt deposits become partly desiccated and shrink, thereby increasing the capacity of the resevoir. Repeated surveys by SCS have documented this behavior; for example, the capacity of Lake Medina in Texas has been partly restored in this manner at least three times.

In contrast to the broad uniform distribution of sediment in many impounding reservoirs, some deposited sediment may be redistributed by sudden large inflows occurring during or after periods of low water level. The upstream parts of the channels may be scoured, and course sediment from the upstream segments may be transported downstream and deposited in areas previously occupied only by clays and silts. This has occurred repeatedly in reservoirs such as Lakes Abilene, Nasworthy, and Waco in Texas and in larger impoundments such as Alamagordo and Elephant Butte Reservoirs and Lake Texoma. The coarse texture of the incoming sediment tends to concentrate deposition around the head of the reservoir. Careful study of the deposits during a reservoir survey can yield many data about the sources and formation of the reservoir deposit. Figure 5–5 shows typical distribution of sediment in reservoirs; figure 5–6 shows excessive accumulation of sediment.

Volume-Weight

The volume-weight of a substance is its weight per unit volume. It is also called dry density or specific weight. This important property of sediment is discussed in Chapter 2, and data are presented there on the volume-weight of reservoir sediment. In general, sediments are compacted by heavy overlying loads, aging, and loss of water. The volume-weight of sediment is affected by the operation of the reservoir and by the sorting and composition of the sediment. Generally, soils and rocks occupy more space after deposition in a reservoir than they did in place in a watershed. This phenomenon has been investigated by Brown and Thorp (1947), Gottschalk and Brune (1950), Jones and Roger (1952), Glymph (1954), Koelzer and Lara (1958), Lara (1970), and others. The sediment occupies 1.1 to about 1.4 times the volume of the same soil in place in the watershed.

Procedures for Determining Cost of Damage

Sediment damage to reservoirs is usually evaluated by SCS economists, who use one of four methods: (1) straight line, (2) sinking fund, (3) sinking fund plus loss in service, and (4) cost of sediment removal. These methods are also used by SCS economists to determine the monetary benefits derived from recommended soil conservation programs (Soil Conservation Service 1964). Geologists should work closely with economists to determine the type of economic analysis to be made and the

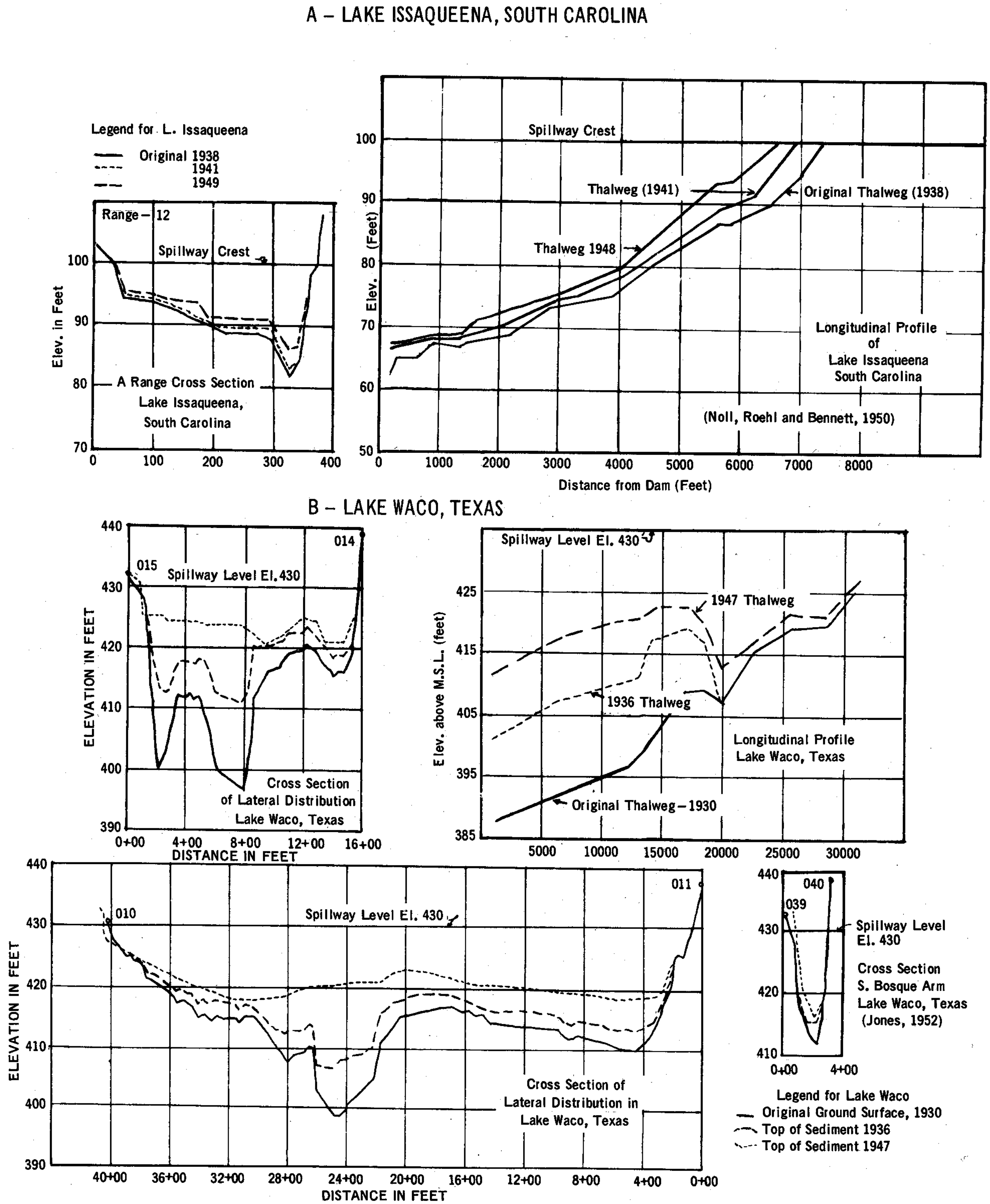

Figure 5–5.—Examples of sediment distribution in reservoirs.

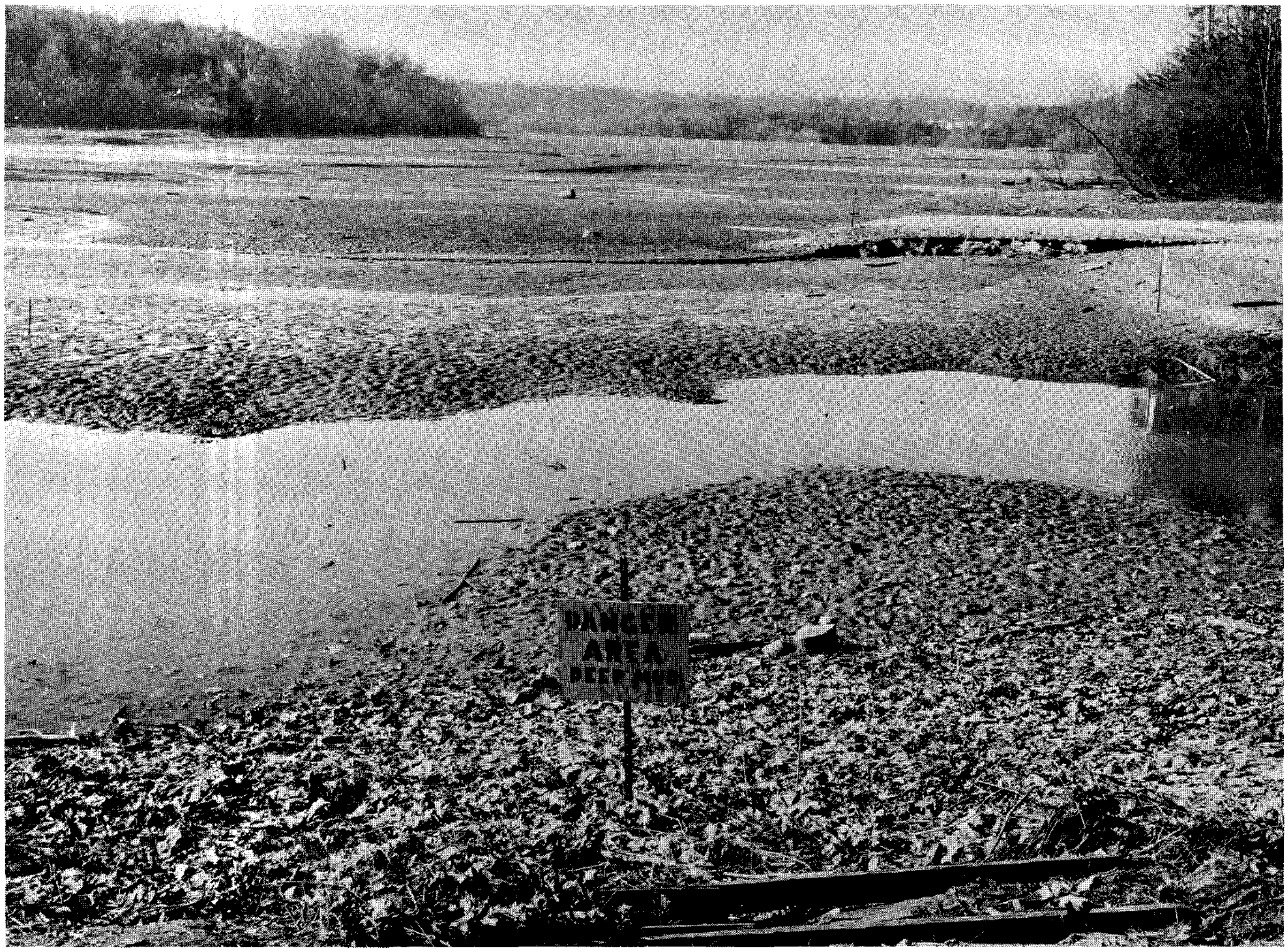

Figure 5–6.—Reservoir sediment accumulation, Lake Accotink, Fairfax County, Va.

kind of field data needed for the specific analysis proposed.

In the straight-line method, the estimated average annual damage is the product of the average annual rate (in acre-feet) of storage loss from sedimentation times the original cost per acre-foot of storage. Geologists must determine the average volume of sediment expected to be deposited annually, with and without installation of the recommended conservation program. For evaluating sediment damage to existing reservoirs the annual rate of sediment deposition can be determined from a reservoir survey, as described in Chapter 7. The future rate of sediment deposition after completing the recommended soil conservation program can be determined by the methods described in Chapter 8 for the design of proposed reservoirs.

The sinking-fund and the sinking-fund plus loss-in-service methods of evaluation are used when the available information clearly indicates that a reservoir will be replaced before there is any significant loss in service. In these methods, the useful life of the structure, with and without the recommended soil conservation program, and the average annual rate of sediment accumulation must be determined.

Evaluating reservoir sedimentation damages on the basis of cost of sediment removal requires estimating sediment yield and the average amount of sediment to be removed annually, with and without the recommended program. This method is used when information indicates that reservoir storage capacity can be maintained by removal of the sediment.

The method selected to evaluate damage to a reservoir depends on the amount of information that can be obtained within the limitations of time and budget and the importance of the benefits accruing from a reduced rate of sediment accumulation. The straight-line method is simple to use and is the preferred method (Soil Conservation Service 1964, p. 5–20).

Sediment Deposits in Harbors and Estuaries

Occurrence

Tides and river discharge intermingle fluvial and beach deposits so that they are heterogeneous in both character and distribution. One of the chief problems affecting the use and maintenance of harbors is sediment accumulation in their basins and channels. Costly dredging and other measures are necessary to maintain ship channels and docking facilities. Accelerated upland erosion and the resulting increased sediment loads have greatly increased deposition in harbors since agriculture and industry developed in the United States. Many records of this increase in deposition are available (e.g., fig. 5–7).

Identification

Identifying the deposits in harbors and estuaries requires investigating both the sediment transported into the area by streams and the sediment produced by erosion of the shores and the reentrants of the bays under investigation. Minerals occurring along the shores or transported into the area may be so distinctive that they can be identified in the shore or outer bay deposits. If these minerals can be identified and traced, some data can be assembled on the relative importance of the sources of the sediment. This mineralogical relationship can also be used to determine the sediment contributed from industrial plants and other sources in the area.

Procedures for Determining Physical Damage

The SCS has investigated sedimentation in some harbors. Brown, Seavey, and Rittenhouse (1939) reported on deposits in the York River estuary in Virginia. Holeman (1962) reported that 141,000,000 yd^3 of sediment had been removed from Baltimore Harbor between 1836 and 1960 by federal agencies at a cost of $26 million. Reports of the U.S. Army Corps of Engineers, including annual reports by the Chief of Engineers and those of the district offices, are good sources of information on sediment removed by dredging. A comparison of maps or aerial photographs made years apart of harbors and estuaries not subject to dredging may indicate the rate of sediment accumulation (fig. 5–7).

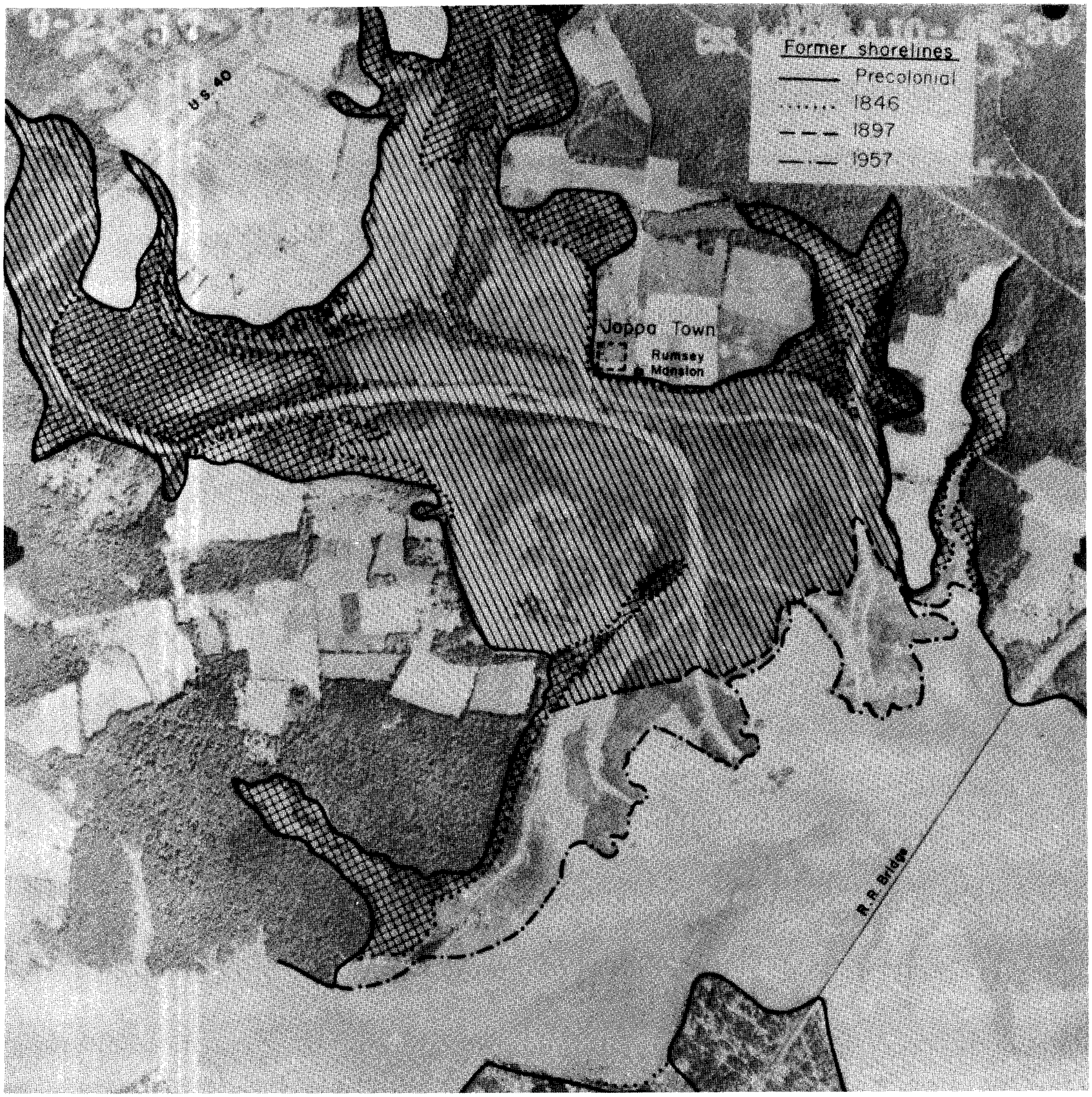

Figure 5–7.—Filled estuary at Joppa Town, Md.

References

Brown, Carl B. 1950. Sediment transportation. *In* Engineering hydraulics, ch. 12, p. 769–857. Hunter Rouse, ed. John Wiley & Sons, Inc., New York.

Brown, Carl B., Louis M. Seavy, and Gordon Rittenhouse. 1939. Advance report on an investigation of silting in the York River, Va. USDA Soil Conserv. Serv. SCS–SS–32, 12 p.

Brown, Carl B., and E. M. Thorp. 1947. Reservoir sedimentation in the Sacramento-San Joaquin drainage basins, California. Soil Conserv. Serv. Spec. Rep. 10, 69 p.

Brune, Gunnar M. 1953. Trap efficiency of reservoirs. Am. Geophys. Union Trans. 34(3): 407–418.

Eakin, H. M. 1939. Silting of reservoirs, revised by C. B. Brown. U. S. Dep. Agric. Tech. Bull. 524, 168 p.

Einstein, Hans A. 1950. The bed-load function for sediment transportation in open-channel flows. U. S. Dep. Agric. Tech. Bull. 1026.

Gilluly, J., A. C. Waters, and A. O. Woodford. 1968. Principles of geology. 3d ed. W. H. Freeman & Co., San Francisco, Calif., 687 p.

Glymph, Louis M., Jr. 1954. Studies of sediment yields from watersheds. Int. Union of Geod. and Geophys., Int. Assoc. Hydrol. 10th Gen. Assem., Rome, Italy, Part 1, p. 178–191.

Gottschalk, L. C. 1965. Trap efficiency of small floodwater-retarding structures. Am. Soc. Civ. Eng. Water Resour. Eng. Conf., March 8-12, Mobile, Ala. Conf. Prepr. 147.

Gottschalk, L. C. 1975. Nature of sedimentation problems. *In* Sedimentation engineering, ch. 1, p. 1–16. Vito A. Vanoni, ed. Manuals and Reports on Engineering Practice No. 54, Am. Soc. Civ. Eng., New York.

Gottschalk, L. C., and G. M. Brune. 1950. Sediment-design criteria for the Missouri Basin loess hills. USDA Soil Conserv. Serv. Tech. Publ. 97.

Happ, Stafford C. 1975. Genetic classification of valley sediment deposits. *In* Sedimentation engineering, ch. 2, p. 286–292. Vito A. Vanoni, ed. Manuals and Reports on Engineering Practice No. 54, Am. Soc. Civ. Eng., New York.

Happ, Stafford C., Gordon Rittenhouse, and G. C. Dobson. 1940. Some principles of accelerated stream and valley sedimentation. U. S. Dep. Agric. Tech. Bull. 695, 134 p.

Holeman, J. N. 1962. Conservation helps lick century-old sedimentation bugaboo. Soil Conserv. 27(11):260–262.

Holeman, J. N. 1967. Sediment brings early death by strangulation to colonial port. Soil Conserv. 32(10):223–225.

Holeman, J. N., and A. F. Geiger. 1959. Sedimentation of Lake Barcroft, Fairfax County, Va. USDA Soil Conserv. Serv. Tech. Publ. 136, 16 p.

Holmes, A. 1965. Principles of physical geology. The Ronald Press Co., New York, 1,288 p.

Jones, Victor H., and Ross E. Rogers. 1952. Aspects of sedimentation in Lake Waco, Waco, Texas. USDA Soil Conserv. Serv. Tech. Publ. 100.

Jones, Victor H., G. W. Renfro, and G. G. Commons. 1954. Problems of sedimentation and water supply in Lake Nasworthy, San Angelo, Texas. USDA Soil Conserv. Ser., Temple, Tex., 26 p.

Koelzer, V. A., and J. M. Lara. 1958. Densities and compaction rates of deposited sediment. Proc. Am. Soc. Civ. Eng., J. Hydraul. Div. 84(HY2), paper 1603, 15 p.

Krumbein, W. C., and L. L. Sloss. 1963. Stratigraphy and sedimentation. 2d ed. W. H. Freeman & Co., San Francisco, Calif., 660 p.

Lara, J. M. 1970. Chapter III. Sediment measurement techniques: reservoir deposits. Proc. Am. Soc. Civ. Eng., J. Hydraul. Div. 96(HY12) :2,417–2,446.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. Fluvial processes in geomorphology. W. H. Freeman & Co., San Francisco, Calif., 522 p.

Noll, J. J., J. W. Roehl, and J. Bennett. 1950. Effect of soil conservation on sedimentation in Lake Issaqueena, Pickens County, South Carolina. USDA Soil Conserv. Serv. Tech. Publ. 95, 20 p.

Roehl, J. W., and J. N. Holeman. 1975. Accelerated valley deposits. *In* Sedimentation engineering, ch. 3, p. 382–385. Vito A. Vanoni, ed. Manuals and Reports on Engineering Practice No. 54, Am. Soc. Civ. Eng., New York.

Soil Conservation Service, U. S. Department of Agriculture. 1964. Economics guide for watershed protection and flood prevention.

Stevens, J. C. 1936. The silt problem. Am. Soc. Civ. Eng. Trans. 101: 207–250.

Trask, P. D., ed. 1950. Applied sedimentation. John Wiley & Sons, Inc., New York, 707 p.

Twenhofel, W. H. 1950. Principles of sedimentation. 2d ed. McGraw-Hill Book Co., New York, 673 p.