CONTENTS

Section I. Introduction
K-1. Purpose and Scope K-1
K-2. Basic Objectives K-1
K-3. Terminology K-2
K-4. Field Facilities K-3
Section II. Reservoir Sedimentation Range Network
K-5. Topographic Maps of Reservoir Area K-3
K-6. Classification of Sediment Ranges K-3
K-7. Numbering Sediment Ranges K-5
K-8. Locating and Spacing Ranges K-7
K-9. Modifications to Existing Range Networks K-9
K-10. Range Monuments and Supplemental Markers K-9
K-11. Permanent Monuments K-9
K-12. Semi-permanent Range Marker K-10
K-13. Temporary Markers K-10
K-14. Horizontal Control for Range Monuments K-10
K-15. Inspection and Maintenance of Field Facilities K-11
K-16. Removal of Vegetation along Range Lines K-11
K-17. Bank Line Survey Data K-11
K-18. Sediment Survey Grids K-11
Section III. Components of Reservoir Sedimentation Surveys
K-19. General K-12
K-20. Field Measurements K-12
K-21. Laboratory Analyses K-12
K-22. Processing Field Data K-12
K-23. Analysis of Field Data K-12
K-24. Initial Surveys K-12
K-25. Use of Echo-Sounders in Initial Surveys K-13
K-26. Preservation of Survey Records K-13
K-27. Resurveys K-13
K-28. Field Survey Methods K-14
K-29. Alternative Methods K-14
K-30. Sediment Specific Weight and Gradation of Deposits K-14
Section IV. Administrative Planning for Surveys
K-31. Justifying the Range Network K-15
K-32. Scheduling Resurveys K-15
K-33. Phasing Resurvey Activities K-15
K-34. Coordination with other Surveys K-15
Section V. Memoranda and Reports
K-35. General K-16
K-36. Subjects to be Covered K-16
K-37. Proposed Reservoir Sedimentation Ranges and Investigations K-16
K-38. Reservoir Sedimentation Survey Data K-16
K-39. Analysis of Reservoir Sedimentation Survey Data K-17
K-40. Submission of Reports K-17
Section VI. Guide Outline for Preparation of Memorandum on Proposed Surveys
K-41. Introduction K-17
K-42. Category A and B Sediment Ranges to Meet Operational Requirements K-18

K-43. Category A and B Sediment Ranges to Meet Planning and Design Requirements..... K-19
K-44. Category C Ranges to Meet Operational Requirements..... K-19
K-45. Category C Ranges to Meet Planning and Design Requirements.... K-20
K-46. Tentative Sedimentation Survey Schedule..... K-20
K-47. Summary and Conclusions..... K-21

LIST OF FIGURES

Figure K-1. Numbering Sediment Ranges..... K-6

LIST OF TABLES

TABLE K-1. Sediment Range Classification..... K-4

APPENDIX K

RESERVOIR SEDIMENTATION INVESTIGATION PROGRAM

Section I. Introduction

K-1. Purpose and Scope. This appendix provides information and instructions for justifying, planning and conducting reservoir sedimentation investigation programs. Topics include:

a. basic objectives,

b. terminology,

c. field facilities,

d. reservoir sedimentation range network,

e. components of reservoir sedimentation surveys,

f. administrative planning for surveys.

K-2. Basic Objectives. Plan and justify the reservoir sedimentation investigation program to achieve the following 4 basic objectives:

a. Functional Objectives. Recognizing that each reservoir site is a limited national resource and that a reservoir sedimentation investigation program is an expensive endeavor, consider the functional objectives of the nation-wide effort when planning a program for a new reservoir. Take into account the probable nature and magnitude of the sediment problems anticipated and the proximity of other reservoir projects in which similar investigations are in progress. Describe the functional objectives in terms of benefits to the specific project, benefits to other projects in the district, benefits to other districts in the Corps, and benefits to the national investment in the development of water resources.

b. Operational Objectives. In all cases provide a limited number of sediment ranges to answer questions associated with the operation of that reservoir. Such needs will vary from project to project, but in general they include the following:

(1) Criteria for the construction of boat docks, recreational facilities, and other structures within the reservoir limits must be modified to include current knowledge on sedimentation.

(2) If sediment yield to the project is large in proportion to storage capacities in multiple purpose reservoirs, sediment deposition will be needed for planning reallocation of storage and for revising reservoir regulation rules to assure optimum utilization of remaining reservoir storage space.

(3) Actual depletion of storage capacity will be needed for forecasting future availability far enough in advance to permit planning and construction

of replacement facilities.

(4) For modifying regulating outlets and water supply intakes and for other facilities adversely affected by sediment accumulations.

(5) In many instances accurate information on the effects of sedimentation on water surface profiles has been used to settle legal claims arising from the operation of the project.

(6) Sediment ranges for observing channel changes downstream from the dam are needed for forecasting additional hydropower head as the result of channel degradation and for ascertaining that the project is not causing channel bed or bank instabilities.

c. Planning and Design Objectives.

(1) Sedimentation investigation programs establish to meet operational objectives will also provide information useful for planning and design of future reservoir projects. However, in most cases additional ranges or grid points, more frequent re-surveys, and a substantially more intensive analyses effort will be required to meet "Planning and Design" objectives than would normally be necessary to meet operational requirements for the project.

(2) Sediment range networks which satisfy "comprehensive" objectives should be provided in regions where planning and design are the most active and where needs are not being satisfied with data from existing investigation programs.

(3) Information needed in connection with the planning and design of a future reservoir involves practically every phase of reservoir sediment investigations (i.e., sediment volumes and distributions to be expected; probable channel changes downstream resulting from reservoir-induced retrogression, etc.).

(4) Field data is most important for projects located where sediment problems are known to be severe.

(5) It is important to establish that sediment problems will not be serious. For example, it is as necessary to demonstrate in project reports that serious sedimentation problems will not occur as it is to forecast the magnitude of a problem. Therefore, plan sediment investigation programs that will provide the necessary information. The field data collected from these programs are sufficiently comprehensive to meet nationwide needs.

d. The Timeliness of Information. Provide the most urgently needed data first and avoid unnecessary duplications of effort with other programs.

K-3. Terminology. Terminology should conform to the glossary, Appendix B. In addition, special terms are introduced in this Appendix. Some are listed here and others in the paragraphs where they are used.

K-4. Field Facilities. Field facilities refers to the network of sedimentation ranges and inflow sampling points required for the sedimentation investigation.

a. Functional Facilities: Sediment ranges and other facilities required to meet functional objectives should be referred to as "Functional" facilities in the justification document.

b. Operational Facilities: Those needed to provide data primarily to meet operational requirements should be referred to as "Operational" facilities.

c. Planning and Design Facilities: Additional facilities required primarily to obtain data to meet planning and design objectives should be referred to as "Planning and Design" facilities (abbreviated "P&D").

Section II. Reservoir Sedimentation Range Network

K-5. Topographic Maps of Reservoir Area. Topographic maps which are prepared for computing reservoir capacity and surface area can serve as the "base map" for planning sediment range networks. The accuracy of the base map is very important because sediment deposits are a small volume relative to the reservoir capacity. Cross sections must be located so surveyed data can be converted from cross section end areas into volume of deposits. An accurate reservoir contour map corresponding to preimpoundment conditions will serve:

a. As the basis for calculating sediment accumulation in future reservoir surveys.

b. As a basis for determining initial cross section profiles of ranges added to the network after the project is in operation.

c. As a basis for adjusting the computations from future surveys when making volume computations of sediment deposits.

K-6. Classification of Sediment Ranges. A "sediment range" is simply a fixed line across a reservoir, a stream channel or flood plain along which elevations are measured. Ranges are classified according to the purposes they will serve and the field conditions affecting survey methods. Classification is illustrated in Table K-1 and described in the following paragraphs.

a. Classification According to Scope of Study.

(1) A "detailed study" range (referred to elsewhere in this manual as "study" range) is one included in a general network established to measuring sedimentation effects on a comprehensive basis.

(2) An "index" range differs from a "study" range in that it is usually more isolated from any correlated "study" network and established for the purpose of obtaining qualitative information.

TABLE K-1. Sediment Range Classification

PERTINENT INFORMATION REGARDING RESERVOIR SEDIMENTATION RANGES		
RANGE DESIGNATION (1)	DEFINITIONS (2)	GENERAL CONSIDERATIONS (3)
A. According to Scope of Study		
Detailed Study Range	A range included in a general network of ranges suitably spaced to provide a basis for detailed surveys.	A network of "detailed study" (or study) ranges will be established where it is deemed necessary to measure sediment effects on a comprehensive basis.
"Index" Range	An "index" range is the same as a "study" range except that it may be more or less isolated from any correlated "study" network.	Index ranges are usually established at locations selected to: (1) provide "index information" for verifying the general magnitude of sedimentation effects without attempting to make detailed quantitative evaluations of such effects and (2) conform as nearly as practicable with minimum costs for initial establishment and for resurveys. For example, index ranges may be established at certain locations simply to verify that sediment effects are negligable in order to refute claims to the contrary or for reconnaissance purposes; at the same time, consideration should be given to the selection of locations with view to practical advantages such as convenience of access and "tieing in" to survey controls already established. (The latter consideration applies to establishment of all ranges but the latitude is usually greater for choosing index range locations.)
B. According to Technical Objectives		
Category "A"	Ranges crossing the main body, and principal arms of a reservoir, that are required as a basis for determining storage capacity depletions resulting from sediment depositions with a degree of accuracy commensurate with general engineering needs.	A network of category A ranges will be required when a "detailed study" of reservoir sedimentation is to be made. The ranges will be sufficient in number and suitably spaced to permit computation of sediment volumes by methods similar to those used in earthwork computations. It is impracticable to precribe rigid criteria for spacing and arranging Category A ranges, but observance of the technical objective involved will serve as a guide to judgement. In general, Category A ranges are established in directions that are approximately normal to the valley, and at points where distinct breaks in reservoir configuration or bottom slopes occur; random ranges at various angles are appropriate in some cases.
Category "B"	Ranges crossing reservoir arms and proximate reaches of tributary channels which are required as a basis for determining the magnitude of sediment depositions and related physiographic changes resulting from backwater influences of the reservoir in locations where knowledge of such effects is deemed necessary.	Category B ranges will be established only where backwater influences are considered likely to create adverse effects on lands or cultural developments, or give rise to claims of adverse effects, but not at all elevations where the reservoir pool may exert hydraulic retardance on inflows during some phase of its operation. From a practical standpoint, it is necessary to evaluate the adverse effects of such backwater influences only in those reaches where it is reasonable to anticipate significant difficulties. Accordingly, proposals for establishing Category B ranges should be supported by appropriate comments indicating why the proposed ranges are considered advisable in the specific instances.
Category "AB"	Ranges having requirements under both Category A and Category B conditions.	This designation should not be applied unless it is considered that the elimination of the range from the network would be seriously detrimental to both objectives A and B. For example, If a particular range, considered essential for the proper study of backwater effects, would have incidental value in computing reservoir sedimentation volumes but could be eliminated without seriously reducing the accuracy of such volume computations, it should be designated only as a Category B range.
Category "C"	Ranges crossing the stream channel and floodway within a limited reach immediately downstream from the dam as required for determining the nature and extent of cross section changes.	Category C ranges are usually considered as part of a general reservoir sedimentation survey program and serve as a means of observing channel changes regardless of the process causing the change (i.e., retrogression, aggradation, degradation, or simply erosion by hydraulic action). However, Category C range installations usually are limited to a reach extending downstream from the dam a sufficiant distance to delineate any substantial lowering of the bed, and/or widening of the channel that is likely to occur as relatively sediment-free water, released from the reservoir, regains its normal transportable load of sediment. The "reach" involved usually extends initially only a few miles downstream, but may be as long as ten to fifty miles or possibly longer in exceptional cases, the length of "reach" tending to increase as retrogression proceeds over a period of years. Category C ranges are usually established for a sufficient distance downstream to provide for studies anticipated within a reasonable period; additional ranges may be added later if needed.
C. According to Field Conditions		
Submerged Range	A range or range-segment across a portion of a reservoir or channel which is frequently submerged for protracted periods and therefore requires the utilization of hydrographic methods for surveys usually involving the use of floating equipment including echo sounders, lead-lines, etc.	The normal operation of multiple purpose reservoirs necessitates the frequent submergence of certain portions of the reservoir area thus causing a major portion of sediment deposition to occur in these areas. In some cases records of sedimentation within the conservation-power pool zones is of greater practical significance than information regarding storage depletion at higher levels. In the interest of economy it may be appropriate that certain ranges in these areas be terminated below elevations of the outer limits of the flood control pool.
"Dry-land" Range	A range that ordinarily must be surveyed by ground survey methods.	This designation generally applies to ranges in all "detention" type reservoirs or channels that are not ordinarily submerged to sufficient depths for long enough periods to permit advantageous use of floating equipment for sediment surveys.

b. Classification According to Technical Objectives. To facilitate the discussion of governing criteria and administrative details, ranges will be identified by categories which are outlined below and discussed in detail in Table K-1.

(1) Category A: Ranges crossing the main body and principal arms of a reservoir. They are required as a basis for determining storage capacity depletions, resulting from sediment deposition, with a degree of accuracy commensurate with general engineering needs.

(2) Category B: Ranges crossing reservoir arms and tributary channels. They are required as a basis for determining the magnitude of sediment deposits and the related changes to water surface profiles.

(3) Category AB: Ranges required for purposes consisting of a combination of category A and category B conditions.

(4) Category C: Ranges crossing the stream channel and flood way within a limited reach immediately downstream from the dam as required for determining the nature and extent of cross section changes.

c. Classification According to Field Conditions.

(1) Submerged: A range or range-segment across a portion of a reservoir or channel that is frequently submerged for extended periods and therefore requires hydrographic survey methods.

(2) Dry-land: A range that ordinarily must be surveyed by ground survey methods.

K-7. Numbering Sediment Ranges. Ranges will be numbered as illustrated in Figure K-1 and described below.

a. Detailed Study Ranges. Ranges intended for "detailed study" purposes will be identified by appropriate serial numbers suffixed by the category letters applicable to the specific range. For example, a range numbered 2-A is number 2 in the sequence and is one in a general network intended for use in detailed studies of reservoir capacity depletions to be expected from sedimentation. The suffix "study" is implied but not shown in this case. In the event a particular range is considered necessary to meet both category "A" and "B" objectives, the number will be suffixed by both letters (i.e., range 11-AB as shown in Figure K-1).

b. Index Ranges. Ranges intended for "index" purposes only will be identified in the same manner as study ranges except that the word "index" will be added parenthetically (i.e., 21-B (Index), 6-C (Index), etc.).

c. Ranges Upstream from Dam. A single series of consecutive numbers will be used to identify ranges in categories "A" and "B."

d. Ranges Downstream from Dam. A separate series will be used to identify ranges in category "C" beginning with No. 1-C for the range nearest

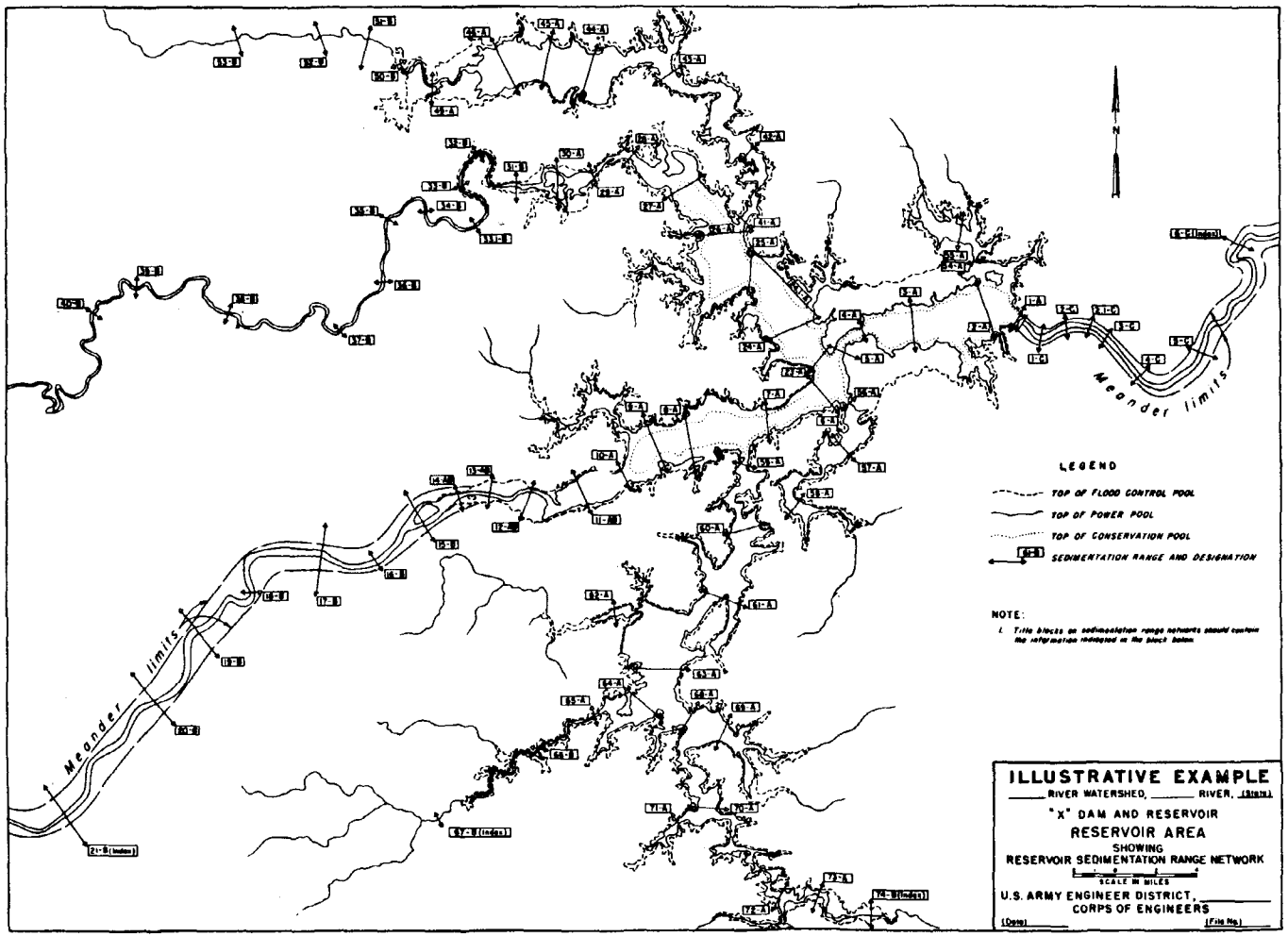

Figure K-1. Numbering Sediment Ranges.

the dam and progressing downstream.

e. Ranges Added to the Network. Ranges subsequently added to an existing network will be identified by a decimal series added to the range number. For example, on Figure K-1 the number 24.1A identifies a range added between 24-A and 25-A.

f. Numbering option. It is advantageous sometime to use a numbering system reflecting the name of the stream that the range crosses. For example, a sedimentation range on New Hope River would be referenced as NH1-C downstream of the dam and upstream of the dam with an "A" or "B" suffix.

K-8. Locating and Spacing Ranges.

a. General Principles. Sediment ranges should be located with respect to the irregular boundaries of the reservoir so the methods presented in this manual can be used to reconstitute the initial volume in the reservoir because volume depletion as the result of sedimentation will be calculated from resurveys of those same ranges.

(1) Equally as important, they should be located with respect to the predicted delta profile so volume of deposits can be calculated from changes in the resurveyed cross sections.

(2) The computation schemes for the volume in the reservoir and the volume of sediment deposited must be compatible.

(3) The ranges should be located by persons who understand the computational procedures that will be utilized to calculate reservoir capacity and sediment depletion, and who know the sedimentation forecasts for the reservoir in question. A field reconnaissance of the area is essential.

(4) However, responsible survey personnel should be authorized to change the proposed range locations, within reasonable limits, so monuments can be set in the most favorable locations.

b. Range Layout Upstream from Dam.

(1) General. Networks are useless if ranges are incorrectly positioned or if they are located too far apart to provide the necessary resolution for the computation scheme. Moreover, the layout should be such that ranges can be easily located in the field and the topographic/hydrographic survey can be conducted with minimum effort.

(a) The first range should be placed at the toe of the dam. Continue along the main stem and include major tributaries. Extended the ranges past the limits of the reservoir pool area to the limits of the study area as described in the chapter on Reservoir Sedimentation in this manual.

(b) Ranges should be oriented normal to the anticipated current pattern after impoundment.

(c) These objectives suggest that developing the range network requires two passes through the reservoir. On the first pass, locate ranges where required to calculate reservoir volume. On the second pass, add those ranges where extra detail is needed. For example, deposition at downstream from major sediment producing tributaries may require extra detail.

(d) It is assumed that total sediment yield during the life of the project has been determined by the time range network design begins, and that the volume and distribution of the sediment deposit has been calculated. If such basic information is not available take a conservative attitude, tending toward closer spacing, when planning the sedimentation ranges.

(e) Since the objective is to determine volume and aerial distribution of sediment deposits in specific areas, ranges must be close enough together to provide records of sediment depths over representative subdivisions of those areas. That spacing varies somewhat with the type of pool as follows:

(2) Spacing in Conservation and Water Supply Pools. The storage capacity of water pools are usually small relative to the capacity allocated to flood control. Therefore, sediment deposition in these pools will cause noticeable problems more rapidly than in the larger, flood control pool. Consequently, advanced information on storage depletion is needed for planning storage reallocation or alterations to hydraulic structures. As a rough guide, a "substantial" sediment accumulation may be assumed to mean 20 percent of the original conservation-water supply storage.

(3) Spacing in Power Pools. The necessity for locating category "A" ranges in the power pool are somewhat less urgent than the cases cited above for water supply and conservation pools, but these ranges will be important where sediment accumulation during project life are expected to exceed 10 to 20 percent of the original capacity.

(4) Spacing in Single Purpose Flood Control Reservoirs. In single-purpose flood control reservoirs, "A" (Index) ranges will satisfy operational needs if the volume of accumulated sediment in 100 years is expected to be less than 20 percent of the original capacity.

(5) Spacing in the Flood Control Pool of Multi-purpose Reservoirs. In multiple purpose reservoirs, where flood control is a primary purpose, the need for category "A" ranges crossing the flood control pool, is greater because of the difficulty of reallocating storage among multiple functions.

c. Range Layout Downstream from Dam.

(1) Ranges should start just downstream from the dam.

(2) In stable channels, characterized by erosion resistant rock beds and banks, a few category "C" (Index) ranges, at selected locations will provide a satisfactory data base to verify that degradation is not a problem to stilling basin performance. In addition, cross sections should be located at all bridge crossings within the study reach. Boundaries of the study area are discussed in the Chapters 2 and 5 in this manual.

(3) In alluvial channels, category "C" ranges will be closely spaced near the dam with spacing increasing in the downstream direction. Locate ranges at hydraulic controls and sediment controls.

d. Special Problem Areas. Ranges are advisable in areas where major sedimentation problems are expected or where visible sedimentation problems may be annoying to reservoirs users and the public at large.

K-9. Modifications to Existing Range Networks. As sedimentation increases in a reservoir, the location of problem areas may change requiring the addition of ranges not originally required. The need for additional ranges may also become apparent after some experience in operation of a particular reservoir has been gained. It is anticipated that modifications of established range networks will be made at the discretion of the District Engineer, as needs arise. However, the need for such additions should be minimized by adequate initial installations. All modifications should be reported to higher authority.

K-10. Range Monuments and Supplemental Markers. Baselines should be established along the reservoir and all ranges should be referenced to the most convenient baseline. Planning will normally allow the use of survey lines previously established for reservoir area surveys.

a. The vertical and horizontal controls used in resurveys must conform exactly with those governing initial survey. Consequently, baselines should be monumented with permanent benchmarks following good survey practices. The monuments should be placed above the reservoir high water line and away from areas that are susceptible to bank caving.

b. A system of secondary monuments or markers of a permanent or semi-permanent nature are desirable.

c. Without exception, accurate, pertinent records of the initial surveys must be preserved.

K-11. Permanent Monuments. Permanent monuments consist of bronze tablets set in stone or concrete emplacements on firm foundations. The base of such a monument should be buried sufficiently to prevent movement by frost action or accidental blows, but may be incorporated in exposed structures if these are known to be stable.

K-12. Semi-permanent Range Markers. Semi-permanent monuments will be used only where restoration by means of surveys, run from permanent survey stations, could be accomplished at reasonable cost. These "monuments" are similar structurally to permanent monuments described in the preceding paragraph, except that requirements for stability and survey accuracy are somewhat less exacting. These usually consist of exposed metal posts (angle irons, etc.) firmly set in the ground, possibly with concrete, exactly on the line of sediment ranges, or otherwise situated to assist in locating alignments. Elevation bench marks are established at the base of these markers. Such range markers are utilized near the edge of permanent pools, or near pool levels attained fairly frequently, in order to reduce land-survey requirements associated with underwater sedimentation surveys. Colors are desirable for identification purposes.

K-13. Temporary Markers. Various forms of temporary markers (flags, painted fence posts, etc.) are used in connection with actual surveys; these are supplementary to more permanent-type markers and monuments.

K-14. Horizontal Control for Range Monuments. Monuments will be moved by natural forces, by accident and by vandalism. The methods for reinstalling monuments are referred to as either "Geodetic Survey Controls," or "Landmark Survey Controls." Although the Geodetic Survey method is preferable from a scientific viewpoint, there are many circumstances in which the Landmark method will be substantially more economical. Therefore, supporting information on the advantages, disadvantages and cost for each method should be included in proposals submitted for an investigation program. A proposal may recommend the application of the "Geodetic" method to some ranges and the "Landmark" method to others.

a. Geodetic Survey Controls. This term applies to conventional triangulation or closed traverse ground surveys with a degree of accuracy of fourth order triangulation standards or better.

(1) Geodetic Survey methods have the advantage of providing a highly reliable basis for relocating monuments in the future regardless of changes in terrain or other modifications in conditions.

(2) Geographic positioning facilitates plotting the ranges on maps for calculating sediment volumes.

(3) Therefore, such methods are preferred in positioning range monuments where the cost is commensurate with the purposes to be served.

b. Landmark Survey Controls.

(1) In some locations closed traverse points are so far from sediment ranges that extensive ground surveys would be required to establish Geodetic Survey Controls. In such cases, it may be advisable, for the sake of economy, to monument range locations to fixed landmarks or permanent structures. The exact geographic position of the references is not essential provided the location of the ranges involved can be accurately positioned in the field. The locations of ranges on maps can usually be approximated satisfactorily for

study purposes.

(2) The disadvantage of the "Landmark Survey" method is the risk that the "landmarks" used as the base location may be destroyed or modified within the project life.

c. Witness Points. Monuments should be tied to as many witness points as practicable regardless of the method used to establish horizontal positions.

K-15. Inspection and Maintenance of Field Facilities. Maintain range markers as needed to avoid relocation surveys. As a practical consideration, have reservoir rangers or other personnel to inspect range markers during trips required for other purposes. Whatever the approach, document it in the plan for the reservoir investigation program.

K-16. Removal of Vegetation along Range Lines. Line-of-sight clearing is required for entire range lengths where land survey methods will be used. In general, where floating equipment is to be used, widths of about 25 feet should be cleared along range segments extending from elevation of the normal pool down to an elevation far enough below elevation of the conservation pool to allow freedom of boat movement.

K-17. Bank Line Survey Data. Changes in bank lines, bar formations and other channel features downstream from a dam are not adequately shown by ranges spaced at normal intervals. A closer spacing of ranges may produce the desired coverage, and in some cases a "survey grid" may be advisable; but such measures are usually not the most economical or satisfactory. Investigate the economics of using controlled aerial mosaics, supplemented with a few selected ranges to provide ground truth to map the area of interest. Periodic visits to the site, the collection of sediment samples from the stream bed, and visual observations of conditions in the problem areas should be included in the study plans. In recommending a data collection program for observing channel and bank line changes, include information on anticipated problems and proposed survey methods. Standardization of procedures is not practicable because of the wide range of physical conditions and economic factors involved. However, the rather common assumption that "sediment ranges are always the proper solution"

K-18. Sediment Survey Grids.

a. General. In lieu of sediment ranges spaced at irregular intervals, "grid" networks are sometimes used as a means of systematically observing changes in stream channels resulting from scour or sediment depositions. The use of survey grids should be considered in special cases, either below dams or in unusual problem areas within reservoir limits, where a higher degree of accuracy in observations is needed than can be attained from the usual range system.

b. Category Designations. Grid networks will have the same technical objectives as sedimentation ranges and will be designated according to A, B, or C categories outlined in Table K-1 (i.e., category A Grid, category B Grid, etc.)

c. Grid Numbering. Grid networks will be identified by appropriate serial numbers applicable to the entire grid when included as a part of a general program of reservoir sedimentation investigations; i.e., "Grid 8-B," or "Grid 1-C," etc. These grid network numbers should be shown on index maps and elsewhere as appropriate.

d. Applications. Extensive use of the grid procedure in connection with reservoir sediment surveys is not anticipated. However, as stated in paragraph 3.1, there are special circumstances where the grid layout of observation points may be economical or otherwise more appropriate than irregular range networks.

Section III. Components of Reservoir Sedimentation Surveys

K-19. General. The term "Sedimentation Survey," is interpreted to include office work, laboratory analyses of sediment samples, field measurements, data processing and analysis.

K-20. Field Measurements. These measurements will include the following:

a. Cross Section Elevations. Survey of established sediment ranges or grids, preparation of topographic maps of special areas, etc., to determine elevations and depths of sediment calculations.

b. Specific Weight of Deposits. Measurements necessary for computation of sediment densities, and sampling required for pertinent determinations of materials involved.

c. Aerial Photographs. Semi-controlled aerial mosaics should be developed.

d. Ground Photographs. Observations, probings, and other pertinent measurements not related to established ranges, such as photographs and pertinent data on delta areas, etc.

K-21. Laboratory Analyses. These will be limited largely to the analyses of samples of sediment deposits to determine gradation of particle sizes and other pertinent data on character of materials.

K-22. Processing Field Data. The processing of field data will include an orderly tabulation of field measurements and office computations necessary to express the quantities and distribution of sediment accumulations.

K-23. Analysis of Field Data. Analysis of field data will include pertinent scientific studies of data obtained from individual surveys, correlations of this data with prior surveys of the same project, and possible correlations with data available from surveys of other projects in the area.

K-24. Initial Surveys. Initial surveys will include the following principal elements:

a. Ground surface profile along the entire length of each range line.

b. Records of any unusual features of terrain, structures, etc., that might influence the interpretation of future resurveys.

c. Ground-view photographs of points of interest such as vegetation, hydraulic controls, and other surface features that might contribute to unusual patterns of currents or sediment deposits.

d. Aerial photographs are desirable if they can be obtained at moderate costs.

K-25. Use of Echo-Sounders in Initial Surveys. In the event there is reasonable assurance that substantial quantities of water will be impounded in the reservoir soon after its completion, it may prove desirable to wait until such impoundment occurs to determine elevation profiles along submerged portions of sediment ranges, in which case echo-sounders would be used; however, dry land portions of such ranges should be surveyed prior to impoundment and other pertinent data referred to in paragraph 6.6 should be recorded for the entire range.

K-26. Preservation of Survey Records. In as much as 5 to 10 years may elapse before some sediment ranges are resurveyed, it is important to properly organize survey notes and place them in suitable form for storage and future use. Consolidating survey information should be prepared for retention in the District and/or Division office. To provide protection against possible loss by fire or other causes, file the original records in fireproof storage or create duplicate copies for filing in a different location from the originals. If desired, this duplication may be accomplished by microfilming in accordance with applicable provisions of AR 340-22.

K-27. Resurveys.

a. Schedules. In general, resurveys of sediment ranges will be scheduled at intervals of 5 to 10 years, depending upon the quantities of sediment anticipated and probable needs for such information. Provisions will also be made for partial or complete resurveys after each major flood, subject to confirmation of necessity after such events occur.

b. Scope of Resurveys. Reconnaissance will be conducted at appropriate times to determine the extent of resurveys needed to conform with objectives. It may be found that complete surveys of some ranges will be required, whereas surveys of limited sections of others will suffice. Partial resurveys may involve consideration of certain portions of the entire network, such as category "C" ranges, when degradation below the reservoir is the subject of principal interest. The reconnaissance information will be incorporated in a concise memorandum to serve as a basis for planning the resurvey and formulating actions necessary to allocate funds for the purpose.

c. Resurvey Reports. Results of resurveys will be incorporated in appropriate memoranda or technical reports so the information will be available for engineering applications in the office as well as for the nation

wide studies.

K-28. Field Survey Methods. Relatively conventional survey procedures and equipment are still appropriate for many uses, while comparatively new approaches are being applied with varying degrees of success in certain circumstances. Personnel engaged in sedimentation investigations should keep informed on progress being made in techniques and equipment, and incorporate pertinent improvements into activities for which they are responsible.

K-29. Alternative Methods. Following is a brief outline of methods that have been used in reservoir surveys.

a. Contour Method. This involves the preparation of detailed topographic maps for areas of interest, the volume of sediment accumulation being determined by comparison of initial contour elevations with those prevailing when the resurvey is made. The procedure has distinct advantages where sediment accumulations are relatively large in the area of special interest and are irregularly deposited.

b. Lead-line and Sounding Rod Surveys. These involve the use of conventional equipment and techniques whereby soundings are made from boats, using sounding rods or sounding lines and lead sounding weights with the aid of tag-lines, standard land surveying instruments, and in some cases range-distance equipment, for determining the positions of measurements. Soundings are taken along established range lines or at grid points. Lead-line or rod soundings on soft deposits are generally less accurate than soundings obtained with suitable echo-sounders; to obtain comparable accuracy in a deep reservoir lead-line or sounding rod surveys are considerably slower than echo-sounder surveys.

c. Echo-Sounder Surveys. The use of suitable echo-sounders usually provides the most economical and satisfactory method of surveying submerged sediment ranges.

d. Dry-Land Surveys. These are required to extend surveys above water lines prevailing when resurveys are made. Sediment depositions may be determined by comparing successive elevation profiles or by a single line-of-levels run after the sediment has accumulated, supplemented by "spudding" measurements to determine sediment depths existing at successive points along the range line.

K-30. Sediment Specific Weight and Gradation of Deposits. These are conducted in conjunction with all surveys. The conventional procedure is to obtain core samples of known volume and determine dry weights in the laboratory. Recently, direct density measurements of undisturbed sediment have been made with a radioactive probe. Reports indicate the radioactive probe method is the superior method.

Section IV. Administrative Planning for Surveys

K-31. Justifying the Range Network. Explain the purpose of each range. Such explanations are not required for justification of the fundamental network, but rather for describing the overall proposal. If the costs involved in providing a comprehensive range network does not substantially exceed that for providing facilities for operational purposes, that is sufficient justification for recommending P&D networks. However, if the additional costs involved are substantial, a more detailed explanation supporting the inclusion or omission of specific facilities will be presented.

K-32. Scheduling Resurveys. Advance notice to all concerned is also necessary to arrange for allocation of funds and to reach proper understandings regarding the scope of surveys that should be undertaken. All of these administrative actions should be completed, insofar as practicable in time to enable field parties to take advantage of favorable weather conditions and favorable reservoir pool levels in order that best results can be realized from the surveys at minimum costs.

K-33. Phasing Resurvey Activities. Attention should first be given to securing adequate field observations and processing the data for future analysis. This action is appropriate, particularly when available funds are inadequate for completion of analyses and reports. However, it is highly important that scheduled activities and allocations of funds also provide for completion of computations, analysis of data and publication of reports on the surveys as promptly as possible in order that the results may be put to engineering use.

K-34. Coordination with other Surveys. Insofar as practicable, sediment ranges surveys should be coordinated with other reservoir surveys for economy.

a. In some cases "Index" ranges may be adequate to meet operational needs. The test is, "Are the field measurements at a specific location adequate for attaining the established objectives?"

b. Is there reasonable evidence that sediment deposits may accumulate, along the range line considered, in sufficient quantity within a significant period of years to be of engineering or legal significance? In reaching a decision on this question, the sedimentary and hydrologic characteristics of streams tributary to the reservoir, the size and functional purpose of the reservoir, and probable plan of operation must be taken into account.

c. Can the available survey equipment and network facilities provide measurements of the anticipated sediment accumulations with a degree of accuracy consistent with engineering requirements?

d. Recognizing that the nature and/or magnitude of problems associated with reservoir-induced sedimentation cannot be accurately predicted, is there reasonable justification for establishing certain ranges or grids as a precaution, even though the probability of substantial sediment depositions in the particular location appears to be small? For example, it may be advisable to install sediment ranges in the vicinity of urban developments where public

relations problems or legal claims may arise in the future, even though the quantity of sediment is expected to be small.

Section V. Memoranda and Reports

K-35. General. Sedimentation investigations pertaining to specific reservoir projects may continue intermittently over many years. Personnel engaged in the studies probably will change long before any particular investigation is completed. The information obtained from surveys will be of immediate and future interest to many engineers not directly involved in the investigations. Accordingly, a systematic series of memoranda and technical reports are essential to the proper accomplishment of program objectives. The scope and format of these individual reports will vary with problems and circumstances involved, but in general the items discussed in the following paragraphs will be covered in an appropriate manner.

K-36. Subjects to be Covered. An appropriate series of memoranda or reports will be prepared by district engineers on the following subjects pertaining to each reservoir sedimentation investigation:

a. Proposed Reservoir Sedimentation Ranges and Investigations.

b. Reservoir Sedimentation Survey Data.

c. Analyses of Reservoir Sedimentation Survey Data.

K-37. Proposed Reservoir Sedimentation Ranges and Investigations. This memorandum will be prepared as soon as construction of a particular reservoir is assured. All information pertinent to formulation of the basic plan for sedimentation ranges, grids, and related facilities will be included, with a clear statement of objectives and circumstances governing specific proposals. Appropriate maps, photographs, and background information should be presented, as discussed in preceding paragraphs. A suggested general outline for this memorandum report, with annotations, is presented as Section VI. It is not required that the outline be adhered to in detail, but appropriate information on the listed items should be included as a basis for review and approval by the division engineer and the Chief of Engineers.

K-38. Reservoir Sedimentation Survey Data.

a. The agencies represented on the Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources, have collaborated in preparation of a set of instructions for compiling reservoir sedimentation survey data in order to promote a uniform assembly of the data and to facilitate future publications of the information in bulletins issued by the subcommittee. These instructions, entitled "Instructions for Compilation of Reservoir Sedimentation Data Summary" and a sample copy of ENG Form 1787 to be used in this connection, are presented in appendix K.

b. A copy of ENG Form 1787 will be completed as soon as practicable after each resurvey of sediment ranges. Promptly following completion of Form 1787, a narrative report describing pertinent features of the resurvey will also be

prepared and forwarded for review as indicated below. In addition to describing soil types and other pertinent features, the report will include appropriate maps, maps, charts, photographs, and tabulations in which data from field notes are presented for use in subsequent analyses (See K-27c).

K-39. Analysis of Reservoir Sedimentation Survey Data. Technical memoranda and reports will be prepared promptly following each comprehensive resurvey or important partial resurvey. These reports will include relatively detailed analysis of new data and pertinent correlations with data obtained from previous surveys of the same project or other projects located in nearby areas of generally comparable characteristics (See K-27).

K-40. Submission of Reports.

a. Proposals for New Investigations. The report will be prepared by district engineers and submitted to division engineer for review and approval. This report, with all transmittal, correspondence, including the division engineer's approving indorsement, will be sent to HQ USACE (CECW-EH-Y), WASH DC 20314-1000 for review and possible comment and filing as monitoring material.

b. Reservoir Sedimentation Data Summary. Two copies of ENG Form 1787 will be prepared by district engineers in accordance with instructions presented and forwarded to HQ USACE (CECW-EH-Y) WASH DC 20314-1000 through the appropriate division engineer.

c. Reports on Sedimentation Surveys or Resurveys. Memoranda and reports will be prepared in accordance with instructions and submitted to division engineer for review and approval. In case of controversial nature, the report may be forwarded for HQ USACE (CECW-EH-Y) WASH DC 20314-1000 for approval at the discretion of division engineers.

Section VI. Guide Outline for Preparation of Memorandum on Proposed Surveys (See Section V, K-37)

K-41. Introduction.

a. References.

(1) Administrative correspondence pertaining to subject project.

(2) Manuals and regulations.

(3) Related project reports and memoranda.

(4) Pertinent technical references.

b. Purpose and Scope of Subject Memorandum.

(1) Review sediment problems related to subject reservoir.

(2) Present considered plans for installation ranges and general investigational program.

(3) Present cost estimates for plans considered.

(4) Present recommendations.

c. Drainage Area Data (Concise Summary).

(1) Location; Size; Topography; Tributaries; Map.

(2) Stream Gaging and Suspended Sediment Stations.

(3) Streamflow Characteristics-General.

(4) Sedimentary Characteristics-General.

(5) Existing Reservoirs and River Improvements Affecting Sediment Problems.

d. Pertinent Data on Subject Reservoir (Concise Summary).

(1) Dam and Appurtenances.

(2) Storage Capacity Allocations (Include an "Area-Capacity" curve or tabulation for subject reservoir).

(3) Reservoir Regulation Plan (concise summary of major provisions).

(4) Real Estate Taking Line Elevations.

(5) Critical Relocations Problems Related to Sediment Problems.

K-42. Category A and B Sediment Ranges to Meet Operational Requirements.

a. General Requirements for Category A Ranges in Subject Reservoir (ref. par. K-6).

(1) Relative magnitude of sediment accumulations considered likely to occur within project life (based on available information pertaining to subject basin and/or other areas in region).

(2) Apparent importance of measuring storage capacity depletions in subject reservoir (ref. par. K-8).

(3) Use of index ranges in subject case.

b. General Requirements for Category B Sediment Ranges (ref. pars. K-6 and K-6b).

(1) Special Problem Areas; Urban.

(2) Special Problem Areas: Agricultural.

(3) Use of Index Ranges.

c. Initial Installations of Category A, AB, and B Sediment Ranges to Meet Operational Requirements.

(1) Proposed network (include layout map and pertinent tabulations of data).

(2) Monumenting: horizontal and vertical controls (ref. pars. K-10 thru K-14).

(3) Estimates of initial installation costs.

(4) Discussion (review concisely any matters that may have a major bearing on decisions involved).

K-43. Category A and B Sediment Ranges to Meet Planning and Design Requirements. (ref. pars. K-2c).

a. General. (Probable needs for planning and design data not met by operational networks in subject reservoir and existing projects.)

b. Additions of category A and B ranges that would be required to assure comprehensive network (ref par K-2c).

c. Estimates of initial installation costs of comprehensive network of category A, AB, and B network (including both operational and P&D ranges).

d. Conclusions and Recommendations Pertaining to Category A, AB, and B Ranges Required for Comprehensive Network.

K-44. Category C Ranges to Meet Operational Requirements. (ref. pars. K-6b and K-34).

a. General requirements for category C ranges (or grids) below subject reservoir (ref. par. K-34).

(1) Description of principal problems considered; relative magnitude of channel changes expected as result of the construction and operation of subject project.

(2) Legal and public relations problems likely to arise from operation of subject project.

(3) Applicability of detailed "Study Ranges" vs "Index" ranges in subject case (ref. par. K-6a).

b. Initial installation of category C ranges to meet operational requirements.

(1) Proposed network (Include layout map and pertinent tabulations of data).

(2) Monumenting and survey controls (ref. pars. K-10 thru K-14).

(3) Estimates of initial installations costs.

(4) Discussion.

K-45. Category C Ranges to Meet Planning and Design Requirements.

a. General. (Probable needs for planning and design data now mey by operational networks below subject reservoir and existing projects).

b. Additions of category C ranges that would be required initially to assure comprehensive network.

c. Probable future additions to category C network as channel changes occur.

d. Estimates of initial installation costs of comprehensive network of category C ranges (or grids).

e. Conclusions and recommendations pertaining to category C ranges required for comprehensive network.

K-46. Tentative Sedimentation Survey Schedule.

a. General.

b. Resurvey of category A and AB ranges.

(1) Reconnaissance surveys of selected key ranges every 5 years, or after each major flood, to determine advisability of more extensive survey.

(2) Complete or partial surveys as found necessary on basis of reconnaissance surveys, but not less than one general survey every 5 to 10 years.

c. Resurvey of category B ranges.

(1) Reconnaissance of critical problem areas at least once each year to determine need for partial or complete resurveys of ranges; routine reconnaissance of all B range areas at least once each 5 years, or after major floods, to determine advisability of more extensive surveys.

(2) Complete or partial surveys as found necessary on basis of reconnaissance, but not less than once every 5 to 10 years if significant changes are apparent.

d. Resurvey of category C ranges.

(1) Reconnaissance surveys every 2 years, or immediately following major floods, to determine advisability of more extensive surveys.

(2) Complete or partial surveys as found advisable on basis of reconnaissance surveys, but not less than one general survey every 5 to 10 years if significant changes are apparent.

e. Memoranda and reports pertaining to subject project (ref. par. K-35 thru K-40. (Indicate the general nature and scope of memoranda to be prepared, insofar as these can be anticipated).

f. Advance planning and budgeting for resurveys** (ref. K-31 thru K-33). (Explain in general terms the extent of resurveys and studies anticipated, and probable funds requirement, if such activities are accomplished. Such information should be adequate to indicate approximately the magnitude of work and costs involved, but all estimates are subject to review and revision annually, if necessary.)

K-47. Summary and Conclusions.

a. Proposed initial installations.

(1) Category A ranges.

(2) Category B ranges.

(3) Category C ranges.

b. Resurveys (Summarize intentions in general terms).

c. Estimated costs.

(1) Initial installations.

(2) Resurveys.

d. Recommendations.

END

Inclosures (to be included in subject report)
1 Drainage Basin Map
2 Area-Capacity Curve for Subject Reservoir
3 Maps of Reservoir Area (or channels) Showing Alternative Sediment Range Layouts