LIST OF ATTENDANCE

Corps Of Engineers - Department Of The Army

Armstrong, H. K.	Office of the Chief of Engineers, Department of the Army, Washington, D.C.
Bertram, G. E.	Office of the Chief of Engineers, Department of the Army, Washington, D. C.
Birrell, D.V.C.	Office of the District Engineer, 1st and Douglas Sts., N. W., Washington, D. C.
Bondurant, D. C.	Office of the District Engineer, P.O. Box 1538, Albuquerque, N. Mex.
Brown, F. R.	U. S. Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss.
Bruce, J. C.	Office of the Division Engineer, Southwestern Division, 1114 Commerce Street, Dallas 2, Tex.
Buffington, R. L.	Office of the District Engineer, 416 Wright Building, Tulsa 2, Okla.
Burrell, G. N.	Office of the District Engineer, 606 Santa Fe Building, Galveston, Tex.
Candrick, Worth	Office of the District Engineer, 33 Customhouse, Charleston 1, S. Car.
Cassidy, W. C.	Office of the Division Engineer, South Pacific Division, Oakland Army Base, Oakland 14, Calif.
Christensen, R. P.	Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City, Iowa
Christiansen, B. J.	Office of the District Engineer, 2301 Grant Street, Mobile 7, Ala.
Coldwell, A. E.	Office of the District Engineer, 416 Wright Building, Tulsa 2, Okla.
Cowan, C. L.	Office of the District Engineer, 830 W. Broadway, Louisville 1, Ky.
Dodge, B. H.	Office of the District Engineer, 751 S. Figueroa Street, Los Angeles 55, Calif.
Douma, J. H.	Office of the Chief of Engineers, Department of the Army, Washington, D. C.
Eden, E. W., Jr.	Office of the Division Engineer, Upper Mississippi Valley Division, 1114 Market Street, St. Louis 1, Mo.
Edstrand, J. P.	Office of the Division Engineer, Missouri River Division, 206 S. 19th Street, Omaha 1, Nebr.
Fish, W. G.	Office of the District Engineer, 10 E. 17th Street, Kansas City 8, Mo.
Fortson, E. P., Jr.	U. S. Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss.
Gardner, J. A.	Office of the District Engineer, 1709 Jackson Street, Omaha 2, Nebr.
Gilcrest, B. R.	Office of the Division Engineer, P.O. Box 1159, U. S. Post Office and Court House, Cincinnati 1, Ohio
Hall, Col. C. L.	The Beach Erosion Board, Dalecarlia Reservation, MacArthur Blvd. and Little Falls Road, Washington 16, D. C.
Happ, S. C.	Office of the District Engineer, 10 E. 17th Street, Kansas City 8, Mo.
Hathaway, G. A.	Office of the Chief of Engineers, Department of the Army, Washington, D. C.
Hespenheide, H. A.	Office of the District Engineer, P. O. Box 119, Fort Norfolk, Norfolk 1, Va.
Hill, A. L.	Office of the District Engineer, 10 E. 17th Street, Kansas City 8, Mo.
Hodges, P. V.	Office of the District Engineer, 909 - 17th Street, Denver 2, Colo.
Jaenichen, P. H.	Office of the Division Engineer, 111 E. 16th Street, New York 3, N. Y.
Johnson, Oliver	Office of the Division Engineer, North Pacific Division, 500 Pittock Block, S.W., 10th Ave. and Washington Street, Portland 5, Oreg.
Leach, L. G.	Office of the Division Engineer, South Atlantic Division, 50 White Hall Street, Atlanta 2, Ga.
Letts, J. O.	Office of the District Engineer, Clock Tower Building, Rock Island, Ill.
Lynde, G. A.	Office of the District Engineer, 903 Ellicott Sq. Bldg., Buffalo 3, N. Y.
Madden, E. B.	Office of the District Engineer, 300 Broadway, Little Rock, Ark.
Maher, T. F.	Office of the District Engineer, 826 U. S. Courthouse and Customhouse, 1114 Market Street, St. Louis 1, Mo.

Mask, W. S.	Office of the District Engineer, Foot of Prytania Street, New Orleans 9, La.
Mason, Dr. M. A.	The Beach Erosion Board, Dalecarlia Reservation, MacArthur Blvd. and Little Falls Road, Washington 16, D. C.
Miller, S. A.	Office of the District Engineer, 909 17th Street, Denver 2, Colo.
Mitchell, B. T.	Office of the District Engineer, 1709 Jackson Street, Omaha 2, Nebr.
Morgan, Russell	Office of the Division Engineer, P. O. Box 1159, U. S. Post Office and Courthouse, Cincinnati 1, Ohio
Morris, G. A.	Office of the District Engineer, P. O. Box 60, U.S. P. O. and Court House Bldg., Vicksburg, Miss.
Morrison, J. A.	Office of the District Engineer, 1400 Penn Mutual Bldg., 6th and Walnut Streets, Philadelphia 1, Pa.
Nelson, M. E.	Office of the District Engineer, 180 E. Kellogg Road, St. Paul 1, Minn.
Pafford, R. J., Jr.	Office of the Division Engineer, Missouri River Division, 206 South 19th Street, Omaha 1, Nebr.
Parson, W. J., Jr.	Office of the District Engineer, 1209 Eighth Street, Sacramento 8, Calif.
Patterson, C. E.	U. S. Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss.
Pedersen, C.	Office of the District Engineer, 628 Pittock Block, S.W., 10th Ave. and Washington St., Portland 5, Oreg.
Pratt, H. K.	Office of the District Engineer, Fort Lincoln, P.O. Box 300, Bismarck, N. Dak.
Rae, Frank	Office of the District Engineer, 909 17th Street, Denver 2, Colo.
Rhodes, R. F.	Office of the District Engineer, Second Floor, P.O. Building, Savannah, Ga.
Schuleen, E. P.	Office of the District Engineer, 925 New Federal Building, Pittsburgh 19, Pa.
Seibert, F. F.	Office of the District Engineer, 909 17th Street, Denver 2, Colo.
Senour, Chas.	Mississippi River Commission, P. O. Box 80, Vicksburg, Miss.
Shane, H. K.	Office of the District Engineer, 416 Wright Building, Tulsa 2, Okla.
Simmons, H. B.	U. S. Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss.
Skidmore, H. J.	Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City, Iowa
Stephenson, E. G.	Office of the Division Engineer, Missouri River Division, 206 South 19th Street, Omaha 1, Nebr.
Strohl, R. M.	Office of the District Engineer, 24th Street and Maryland Ave., Baltimore 3, Md.
Thomas, J. I.	Office of the Division Engineer, Great Lakes Division, 1660 E. Hyde Park Blvd., Chicago 15, Ill.
Trainor, C. F.	Office of the District Engineer, Second Floor, P. O. Building, Savannah, Ga.
Van Faasen, J. B.	Office of the District Engineer, Administration Building, Fort Peck, Mont.
Waara, Tarmo	Office of the District Engineer, 1709 Jackson Street, Omaha 2, Nebr.
Westby, H. O.	Office of the District Engineer, 1400 Textile Tower Bldg., 7th and Olive Way, Seattle 1, Wash.
Wilson, P. A.	Office of the District Engineer, P. O. Box 1538, Albuquerque, N. Mex.

Department of the Interior

Endersbee, W. J.	Office of Land Utilization, Washington, D. C.
Forsling, C. L.	Office of the Secretary, Washington, D. C.
Sloan, W. G.	Missouri Basin Field Committee, Billings, Mont.

Bureau of Reclamation - Department of the Interior

Barclay, M. G.	Area Planning Office, Oklahoma City, Okla.
Blanks, R. F.	Branch of Design and Construction, Denver, Colo.
Blote, M. H.	Region 2, Sacramento, Calif.
Borland, W. M.	Branch of Project Planning, Denver, Colo.
Brown, W. E.	Branch of Design and Construction, Denver, Colo.
Byrns, F. E.	Branch of Operation and Maintenance, Washington, D. C.
Darnell, J. L.	Region 5, Amarillo, Tex.
Dicke, L. H.	Branch of Project Planning, Denver, Colo.
Dixon, J. W.	Branch of Project Planning, Washington, D. C.
Dubrow, M. D.	Branch of Project Planning, Denver, Colo.
Garstka, W. U.	Branch of Project Planning, Denver, Colo.
Hebert, D. J.	Branch of Design and Construction, Denver, Colo.

Jacobson, C. B.	Region 4, Salt Lake City, Utah
Jenkins, D. S.	Branch of Project Planning, Washington, D. C.
Kidder, A. W.	Branch of Design and Construction, Denver, Colo.
Koelzer, V. A.	Branch of Project Planning, Washington, D. C.
Lane, E. W.	Branch of Design and Construction, Denver, Colo.
Lewis, M. R.	Region 1, Boise, Idaho
Lindley, J. G.	Region 2, Sacramento, Calif.
Lord, R. C.	Area Planning Office, Albuquerque, N. Mex.
Maddock, Thomas, Jr.	Branch of Project Planning, Denver, Colo.
Martin, H. M.	Branch of Design and Construction, Denver, Colo.
McClellan, L. N.	Branch of Design and Construction, Denver, Colo.
McConaughy, D. C.	Branch of Design and Construction, Denver, Colo.
McGrath, B. R.	Branch of Design and Construction, Denver, Colo.
Meissner, V. S.	Branch of Design and Construction, Denver, Colo.
Mitchell, D. S.	Region 7, Denver, Colo.
Rea, J. E., Jr.	Area Planning Office, Oklahoma City, Okla.
Riesbol, H. S.	Branch of Project Planning, Denver, Colo.
Schacht, D. W.	Branch of Project Planning, Denver, Colo.
Seavy, L. M.	Branch of Project Planning, Denver, Colo.
Shaffer, F. B.	Region 7, Denver, Colo.
Sharkey, P. L.	Region 5, Amarillo, Tex.
Skrinde, R. A.	Branch of Design and Construction, Denver, Colo.
Slaughter, R. F.	Region 7, Denver, Colo.
Spencer, J. N.	Region 7, Denver, Colo.
Stanley, J. W.	Region 3, Boulder City, Nev.
Stone, A. A.	Branch of Design and Construction, Denver, Colo.
Stubblefield, G.	Region 2, Sacramento, Calif.
Thatcher, G. C.	Region 6, Billings, Mont.
Thomas, C. W.	Branch of Design and Construction, Denver, Colo.
Waggoner, E. B.	Branch of Design and Construction, Denver, Colo.
Warnock, J. E.	Branch of Design and Construction, Denver, Colo.
White, H. E.	Branch of Design and Construction, Denver, Colo.
Wigle, D. A.	Branch of Design and Construction, Denver, Colo.

Fish and Wildlife Service - Department of the Interior

Wilson, E. O.	Billings, Mont.

Geological Survey - Department of the Interior

Ames, F. C.	Surface Water Division, Oklahoma City, Okla.
Bell, F. M.	Surface Water Division, Chattanooga, Tenn.
Benedict, P. C.	Quality of Water Division, Lincoln, Nebr.
Colby, B. C.	Quality of Water Division, Iowa City, Iowa.
Connor, J. G.	Quality of Water Division, Lincoln, Nebr.
Cooper, A. E.	Surface Water Division, Iowa City, Iowa
Crawford, L. C.	Surface Water Division, Iowa City, Iowa
Culbertson, D. M.	Quality of Water Division, Norton, Kans.
Hanly, T. F.	Quality of Water Division, Worland, Wyo.
Howard, C. S.	Quality of Water Division, Albuquerque, N. Mex.
Kaye, C. A.	Geologic Branch, Denver, Colo.
Love, S. K.	Quality of Water Division, Washington, D. C.
Mangan, J. W.	Surface Water Division, Harrisburg, Pa.
Melin, K. R.	Water Utilization Division, Los Angeles, Calif.
Myers, R. E.	Surface Water Division, Iowa City, Iowa
Peterson, H. V.	Water Utilization Division, Los Angeles, Calif.
Schaefer, F. T.	Surface Water Division, Lincoln, Nebr.
Trask, P. D.	Geologic Branch, Washington, D. C.
Vice, R. B.	Surface Water Division, Dickinson, N. Dak.
Whitaker, G. L.	Surface Water Division, Cambridge, Nebr.
Wilson, M. T.	Surface Water Division, Salt Lake City, Utah
Woolley, R. R.	Water Utilization Division, Salt Lake City, Utah
Wright, J. J.	Quality of Water Division, Lincoln, Nebr.

Bureau of Indian Affairs - Department of the Interior

Berry, W. H.	Soil and Moisture Conservation Operations, Phoenix, Ariz.
Flory, E. L.	Soil and Moisture Conservation Operations, Chicago, Ill.
Rupkey, R. H.	Irrigation Division, Phoenix, Ariz.

Bureau of Land Management - Department of the Interior

Brown, A. W.	Region 4, Salt Lake City, Utah
Denny, B. C.	Land Classification Division, Washington, D. C.
Nielson, R. D.	Region 3, Billings, Mont.

Forest Service - Department of Agriculture

Adair, J. S.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Adams, J. A., Jr.	Region 4, Ogden, Utah
Bailey, R. W.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Baudendistel, M. E.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Buck, C. C.	California Forest and Range Experiment Station, Berkeley, Calif.
Croft, A. R.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Dortignac, E. J.	Rocky Mountain Forest Experiment Station, Fort Collins, Colo.
Goodell, B. C.	Rocky Mountain Forest Experiment Station, Fort Collins, Colo.
Gould, C. A.	Region 2, Denver, Colo.
Ilch, D. M.	California Forest and Range Experiment Station, Berkeley, Calif.
Kirby, F. L.	Region 2, Denver, Colo.
Kraebel, Charles	California Forest and Range Experiment Station, Berkeley, Calif.
Lassen, Leon	Division of Forest Influences, Washington, D. C.
Lobenstein, H. L.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Martin, W. P.	Southwestern Forest and Range Experiment Station, Tucson, Ariz.
Munns, E. N.	Division of Forest Influences, Washington, D. C.
Olson, O. C.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Retzer, J. L.	Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.
Rich, L. R.	Southwestern Forest and Range Experiment Station, Tucson, Ariz.
Rosa, J. M.	Intermountain Forest and Range Experiment Station, Ogden, Utah
Spencer, J. W.	Region 2, Denver, Colo.
Storey, H. C.	California Forest and Range Experiment Station, Berkeley, Calif.
Whelan, D. E.	Northeastern Forest Experiment Station, Philadelphia, Pa.
Wilm, H. G.	Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Soil Conservation Service - Department of Agriculture

Brown, Carl B.	Office of Research, Washington, D. C.
Brune, G. M.	Regional Office, Milwaukee, Wisc.
Einstein, H. A.	Cooperative Laboratory, Soil Conservation Service and California Institute of Technology, Pasadena, Calif.
Elmendorf, H. B.	Regional Office, Albuquerque, N. Mex.
Gottschalk, L. C.	Office of Research, Washington, D. C.
Hansen, O. C.	Regional Office, Lincoln, Nebr.
Jones, V. H.	Regional Office, Fort Worth, Tex.
Rogers, R. E.	Regional Office, Fort Worth, Tex.
Thorp, E. M.	Regional Office, Albuquerque, N. Mex.
Vanoni, V. A.	Cooperative Laboratory, Soil Conservation Service and California Institute of Technology, Pasadena, Calif.

Tennessee Valley Authority

Churchill, M. A.	Knoxville, Tenn.
Fry, A. S.	Knoxville, Tenn.
Okey, C. W.	Knoxville, Tenn.

Federal Power Commission

Walker, L. C.	Chicago, Ill.

Coast and Geodetic Survey - Department of Commerce

Murray, H. W.	Hydrographic Surveys Section, Washington, D. C.

States and Municipalities

Brown, M. E.	Illinois Division of Waterways, Springfield, Ill.
Durke, R. C.	Los Angeles Department of Power and Water, Los Angeles, Calif.
Pemberton, C.	Illinois Division of Waterways, Springfield, Ill.
Youngquist, C. V.	Ohio Water Resources Board, Columbus, Ohio
Ziemer, G. L.	Iowa Conservation Commission, Des Moines, Iowa

Universities

Albertson, M. L.	Iowa Institute of Hydraulic Research, Iowa City, Iowa
Boyer, M. C.	Iowa Institute of Hydraulic Research, Iowa City, Iowa
Christensen, N. A.	Colorado A and M College, Ft. Collins, Colo.
Dai, Y. B.	Iowa Institute of Hydraulic Research, Iowa City, Iowa
Johnson, J. W.	University of California, Berkeley, Calif.
Lamb, C. A.	Iowa Institute of Hydraulic Research, Iowa City, Iowa
Laursen, E. M.	Iowa Institute of Hydraulic Research, Iowa City, Iowa
Rouse, Hunter	Iowa Institute of Hydraulic Research, Iowa City, Iowa
Serr, C. F., III	Colorado A and M College, Ft. Collins, Colo.

Foreign Countries

China

Chich-Chou, Yang	Yangtze River Commission, c/o Bureau of Reclamation, Denver, Colo.
Chu, H.	Student Trainee, Bureau of Reclamation, Denver, Colo.
Chungynie, Fung	Yangtze River Commission, c/o Bureau of Reclamation, Denver, Colo.
Fung, L. H.	Yangtze River Commission, c/o Bureau of Reclamation, Denver, Colo.
Kwei-King, Yao	Yangtze River Commission, c/o Bureau of Reclamation, Denver, Colo.
Loh, Ching-Kai	Yangtze River Commission, c/o Bureau of Reclamation, Denver, Colo.
Wang, Yi-Fu	Yangtze River Commission, c/o Bureau of Reclamation, Denver, Colo.

India

Ahmed, Iftekhar	Student Trainee, Bureau of Reclamation, Denver, Colo.
Berry, Narendra K.	Punjab Irrigation District
Doddiah, D.	Government of India
Hussain, Mahmood	Student Trainee, Bureau of Reclamation, Denver, Colo.
Kapila, Indar P.	" " " " " " "
Mohanty, H. K.	" " " " " " "
Rashid, Abdur	" " " " " " "
Shrikant, Ranbir S.	" " " " " " "
Vaidyanathan, P. H.	" " " " " " "
Vankata Rama Red, M. S.	Visitor

New Zealand

Menzies, G. C.	Public Works Department, Washington, D. C.

Others

Houk, I. E.	Consulting Engineer, Denver, Colo.
Jenkins, J. H.	Department of Agriculture (retired), Denver, Colo.
Matthes, G. H.	American Society of Civil Engineers, New York, N. Y.
Wier, R. K.	Armco, Denver, Colo.

ADDRESS OF WELCOME

by L. N. McClellan*

I am pleased this morning to welcome you to this conference and to extend to you the hospitality of the Bureau of Reclamation, on behalf of Commissioner Straus and Chief Engineer Young, to make the facilities of the Bureau available during your visit. Unfortunately, Chief Engineer Young is away on vacation and is unable to be here this morning.

I understand that this is the first meeting of this kind where the entire program is devoted specifically to the sedimentation problem. This in itself constitutes somewhat of a milestone in the progress in this particular field of technical study. The Bureau, of course, considers it quite an honor to extend its facilities and be host at a meeting of this sort. We are delighted to have you here.

Now I understand that Mr. Brown, the Chairman of the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee, will outline the scope and functions of this conference. Therefore, I will not attempt to go into that phase. Those in charge of the program suggested that I might give you a brief history of the Federal Center, as it is now called, and explain why the Bureau of Reclamation is now establishing its headquarters at this place.

The Federal Center, or the Arms Plant as it was called during the war, was built by the Army Engineers in 1941 prior to Pearl Harbor, for the purpose of manufacturing small arms ammunition. The plant was leased to the Remington Arms Company, which operated it and manufactured millions of rounds of 30-caliber shells. The plant made quite a record and turned out many shells at a much faster rate than the plant had originally been designed for. As the war progressed it developed that the military need for small arms ammunition was adequate, and this plant, along with several others throughout the country, was shut down. Later in the war a need for larger caliber shells developed, and the Kaiser Industries took over part of the plant and converted it to the manufacture of 155-mm. and 8-inch shells. The large black building with the peculiar ventilators in the roof which you noticed as you drove up was the forge plant for the Kaiser Industries. This Building 1-B which we are now in was also convered by the Kaiser Industries for the manufacture of 9-mm. shells later in the war program. The tooling-up was just about completed at the end of the war, and the manufacture of 90-mm. shells was never actually started.

When the war was over this plant was idle for a time and considered a surplus property. During the war the Bureau of Reclamation had an expanded program, principally in connection with installation of generator facilities to provide power for the manufacture of aluminum, magnesium, and other war industries, and in expanding the organization to take care of that program it was necessary to rent additional space in various buildings downtown. When the war was over the Bureau was called on for additional expansion of its program, the development of large irrigation projects to make farm homes available for returning veterans, and this enlargement program necessitated a further expansion of the Bureau's staff. There was just no office space available in downtown Denver. Plans were then under consideration for disposal of the Arms Plant and what use should be made of it. Consideration was given to making it available to a number of small industries, but the critical need for office space on the part of the various Federal agencies in this area finally decided that this Arms Plant should be converted to meet that need. The name was changed to "Denver Federal Center," the buildings were turned over to the Federal Buildings Administration and the various Governmental agencies in need of

* Assistant Chief Engineer, Electrical and Mechanical, Branch of Design and Construction, Bureau of Reclamation, Denver, Colo. (for Walker R. Young, Chief Engineer).

office space were allotted various buildings and space. The Federal agencies which have been allotted space include the Veterans Administration, Forest Service, Geological Survey, Public Roads Administration, War Assets Administration, and Bureau of Reclamation.

The first unit of the Bureau organization moved was the Hydraulics Laboratory, which moved here in March 1946. Additional units of the laboratory facilities were moved as space became available. Now I believe the laboratories are practically 100 percent moved out here. Other units of the Bureau's organization have been moved into Building 1-A, immediately south of this building. I believe the Dam Design Division, Electrical-Mechanical, Structural, Architectural Divisions, Tracing Division, Hydrology Division, and perhaps others are now out here. Additional design divisions will be moved here as soon as the space can be made available. We now expect the administrative offices will be moved out here the middle of the summer, provided the present strike in the building industry doesn't further delay the remodeling program.

In closing, I regret to announce that E. W. Lane, who is a consulting hydraulic engineer on the staff of the Chief Engineer and who intended to take a prominent part in this conference, is ill. The paper which he was to have read will be read by Mr. Herbert of the Hydraulic Laboratory staff. We are very sorry that Mr. Lane's illness prevents him from participating in the discussion of various papers. Those discussions have been assigned to others in our organization.

Again I want to express our pleasure in having you all here for this conference. I hope your visit will be enjoyable and that the conference will be both profitable and interesting.

PERSPECTIVE ON SEDIMENTATION - PURPOSE OF CONFERENCE

by Carl B. Brown*

On behalf of the Government agencies represented on the Federal Inter-Agency River Basin Committee, I welcome you to this conference. This is the first technical meeting of national scope ever held in this country on the problems of sedimentation as they are of concern to the engineer and conservationist. The conference is an outgrowth of increasing recognition of the importance and widespread ramifications of sediment in the planning of river basin developments and in the conservation of land and water resources.

A few Federal, State, and local agencies in the United States have investigated one or another aspect of the sediment problem from time to time during more than a century. It has only been within the past 15 to 20 years, however, with the advent of expanded Federal programs of flood control, reclamation, power development, navigation improvements, and soil conservation, that the true import of sediment has come to be recognized.

The first attempt to measure the sediment load of streams in this country was made a little more than 100 years ago on the Mississippi River by the United States Army Engineers. The first studies of reservoir silting date back only to the 1890's. The Corps of Engineers has sampled the suspended load of the Mississippi River during various periods from as early as 1838; of the Missouri River from as early as 1879. In connection with preparation of the so-called 308 Reports on flood control, navigation, power, and other phases of river basin development, beginning in the late 1920's, the Corps of Engineers carried on extensive suspended-load sampling at many stations in the Missouri River Basin, the Upper Mississippi and tributaries, and on other streams. During this period, also, the Engineers made surveys of a number of reservoirs to determine the effects of sedimentation. Since 1940, or slightly earlier, many of the District Offices of this agency have begun extensive programs of suspended-load sampling and of sedimentation surveys of all reservoirs for which the Engineers are responsible. The Corps of Engineers has also conducted numerous experiments at the Vicksburg, Miss., laboratory and elsewhere on the effects of sediment on river behavior.

The Geological Survey sampled the suspended load of the Rio Grande at El Paso in 1889 and 1890, and in cooperation with the International Boundary Commission during various periods subsequent to this date. During 1906-1907 this agency sampled the suspended-sediment load of many streams throughout the United States for a period of one to two years. In 1925 the Survey began a sampling program in the Colorado River and tributaries which has continued to date. In 1934 to 1940 the Survey cooperated with the Soil Conservation Service and Forest Service in measuring the suspended-sediment load in numerous small streams throughout the United States. The Survey made an investigation of reservoir silting in La Grange Reservoir on the Tuolumne River, California, in 1905, and considered this problem on the Salt River, Arizona, in a publication issued in 1897. In 1946 the Survey began an extensive program of sampling on tributaries of the Missouri River.

The International Boundary Commission has sampled the sediment load of the Rio Grande at various points continuously since 1928.

The Bureau of Reclamation began suspended-sediment sampling on the Colorado River at Yuma, Ariz., in 1909, and has done similar sampling on other streams at various dates. The Bureau has made sedimentation surveys from time to time on a number of reservoirs under its control -

* Sedimentation Specialist, Office of Research, Soil Conservation Service, Washington, D. C., and Chairman, Sedimentation Subcommittee, Federal Inter-Agency River Basin Committee.

notably Lake McMillan on the Pecos River in 1910 and subsequently, Elephant Butte Reservoir on the Rio Grande in 1916 and at intervals thereafter, and Guernsey Reservoir on the North Platte River from time to time since 1927. The Bureau has also made extensive measurements of density currents in Lake Mead, and of degradation of the channel of the Colorado River from Hoover Dam to Yuma. It has devised and installed unique desilting works at Imperial Dam on the Colorado River to remove the sediment load at the entrance of the new All-American Canal. In 1946 the Bureau developed a program of systematic studies of reservoir, stream-channel, canal, and related sedimentation problems.

The Division of Irrigation of the Soil Conservation Service, U. S. Department of Agriculture (formerly of the Office of Experiment Stations and Bureau of Agricultural Engineering), sampled the suspended load of the Brazos and Wichita Rivers in Texas in 1900-1902; made a study of the sediment load of the Colorado River of the West and of various irrigation canals leading from it in 1917-1918; and in 1924 began systematic measurements of the sediment load of Texas streams, a program which has continued to date. The Division made sedimentation surveys of several reservoirs in Texas in the early 1920's. It has also made extensive studies of methods for removing sediment from irrigation canals and of desilting basins for controlling debris from mountain torrents.

Since the early 1930's the Forest Service of the U. S. Department of Agriculture has made a number of reservoir sedimentation surveys, particularly in California, and has made other studies of sediment movement in streams and small watersheds within the National forests.

In 1934, the Soil Conservation Service, U. S. Department of Agriculture, established a Sedimentation Section in its Office of Research to make systematic studies of the causes and effects of sedimentation resulting from accelerated soil erosion. As part of these research studies and, also, after 1937, as part of the flood control surveys made jointly with the Forest Service under authority of the Flood Control Act of 1936, the Service has completed numerous sedimentation surveys in all parts of the country. Detailed sedimentation surveys have been made on about 150 reservoirs and reconnaissance investigations on some 300 other reservoirs. New methods have been developed for determining a stream-channel and flood-plain aggradation and scour, and surveys have been made on some 50 representative valleys. Research on suspended- and bed-load transportation and on density currents in reservoirs has been carried on in cooperation with the California Institute of Technology and at various field locations. Numerous studies of sediment control methods and the effects of various conservation measures on rates of sediment production have been made at experiment stations and in experimental watersheds in various parts of the country.

The Tennessee Valley Authority began in 1934 a systematic program of measurement of the suspended load of streams and surveys of principal reservoirs in the TVA system.

Various other agencies have made important contributions through surveys and measurements, notable among which have been the Office of Indian Affairs and the Fish and Wildlife Service in the U. S. Department of the Interior; the North Carolina Department of Conservation and Development; the Los Angeles County Flood Control District; the East Bay Municipal Utilities District of Oakland, Calif.; the Salt River Valley Water Users Association of Phoenix, Ariz., the University of Texas through the late Dean T. U. Taylor; the Aluminum Company of America; the city of Baltimore; and many others.

Since about 1935 there has been a growing recognition of the significance of the sediment problem and of the need for coordination of efforts in its investigation. This need led in 1939 to the formation of a Federal interdepartmental committee on the measurement and analysis of sediment loads in streams. Under the sponsorship of this committee a cooperative research project was established at the Iowa Institute of Hydraulic Research, University of Iowa, to develop improved samplers and field and laboratory techniques for sediment-load investigations. The need for cooperation and coordination on a broader scale led the Federal Inter-Agency River Basin Committee in May 1946 to establish a Subcommittee on Sedimentation. This Subcommittee absorbed the functions of the old interdepartmental committee and has been instrumental in starting a number of new projects, the nature and scope of which have been reported in the Committee's monthly minutes, quarterly news-letter supplements, and other reports that have been distributed from time to time to field offices.

Figure 1 has been prepared to show the ramifications of the sediment problem in some perspective. This diagram relates the principal types of sediment problems to the principal classes of enterprise or natural resources which they affect. The harmful effects of sedimentation may be divided into five major categories as shown in the boxes at the bottom of the diagram:

(1) Sediment concentration in water may be harmful even though the stream is fully competent to carry all of its load without deposition. High turbidity may destroy the value of the stream for fish and wildlife. It makes the stream or lake undesirable for swimming. Coarse sediment in transportation may damage power turbines. Fine sediment must be filtered at considerable cost before the water is acceptable for public, domestic, and industrial uses.

(2) Sedimentation in improved channels, floodways, ditches, and canals used for navigation, drainage, irrigation, and flood control must be prevented or the sediment removed if these improvements are to function effectively.

(3) Sedimentation in reservoirs causes loss of storage capacity, which depreciates the value of the storage development and causes other losses such as increased evaporation, decreased recreational opportunities, and impaired esthetic values.

(4) Deposition on land, improvements, and habitats, mainly during flood flows, causes severe damages in many areas to agricultural land, to urban areas, to transportation facilities, and to native wildlife.

(5) In addition to these direct damages, aggradation of stream channels and natural or artificial floodways has the effect of increasing flood stage for any given discharge. Consequently the area inundated and the extent of flood-water damages may be increasing as a result of sedimentation, although the volume and rate of runoff remains substantially the same. As floods affect all classes of enterprise and resources shown on this diagram, this is an all-inclusive form of damage.

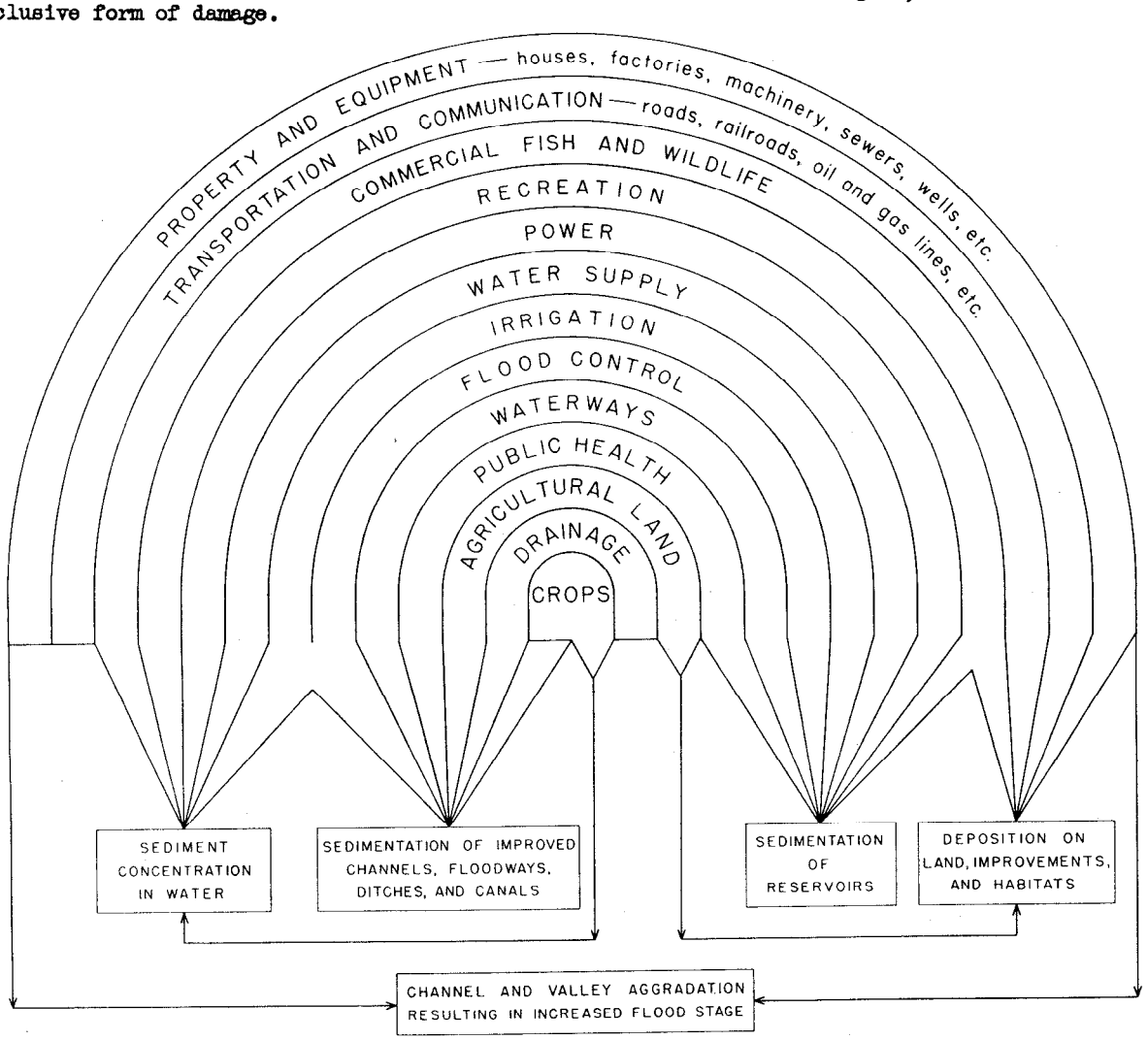

Figure 1. EFFECTS OF SEDIMENTATION

These five categories of sediment transport and sedimentation adversely affect 13 major classes of enterprise or natural resources. The relationships are shown in the diagram.

The economic significance of sedimentation is, I believe, of considerable pertinence to this conference. Are we gathered here to consider the technical aspects of a subject which, although it may be widely recognized, is of relatively little importance to the national economy? Or is sediment a problem that should be of grave and lasting concern to engineers and conservationists? How do sediment damages compare in the aggregate with the damages from flood waters? What are the over-all effects of sediment on agriculture; on water supply; on power production; on irrigation; and on flood control?

In an effort to answer some of these questions - to set up a scale of comparison - crude as it must be in the light of existing information, I have estimated the cost of sediment to the classes of enterprise shown in Figure 1. The total average annual damage from all forms of sediment and sedimentation comes to approximately $175,000,000. The limit of error in this estimate probably is little if any greater than the error in estimates of the total annual flood damages in the United States. United States Weather Bureau data show an average annual flood damage of $100,657,000 for the 20-year period, 1925-1944. The Forest Service has estimated the total annual flood and sedimentation damages at $250,000,000, based on data contained in 121 flood control survey reports, 6 by the Department of Agriculture and 115 by the Corps of Engineers, plus 99 preliminary examination reports by the Department of Agriculture. Altogether these reports cover 51 percent of the area of continental United States. The data were expanded on an areal basis. It is known, however, that several major classes of sedimentation damage, such as damage to reservoirs and agricultural land resources, were not evaluated in many of these reports.

The total sedimentation damage estimate includes these items:

(1) Damage to agricultural land resources from overwash of infertile material, impairment of natural drainage, and swamping due to channel aggradation, associated flood-plain scour and bank erosion - $50,000,000. This estimate is based on data collected in field surveys of 34 watersheds on which flood control surveys have been completed, or nearly completed, by the Department of Agriculture. These watersheds contain about one-eighth of the land area of the United States, and being widely distributed should represent a fair average. The damage data were computed on a per-acre basis and expanded to the total land acreage of the country. If this figure seems large, it should be borne in mind that sedimentation damage to agricultural land is cumulative, whereas flood-water damage is recurrent. For example: On a given piece of valley land which is overflowed on an average of once in 5 years, sufficiently to produce a total crop loss, the loss is one-fifth of the potential net return. Take the same piece of land, however, and allow channel aggradation to raise the water table under the land so that crops cannot be grown at all, and the loss of return every year is 5 times as great.

(2) Damage from sedimentation in storage reservoirs used for power, water supply, irrigation, flood control, navigation, recreation, and multiple purposes - $50,000,000. This estimate is based on the results from surveys of some 600 out of approximately 10,000 reservoirs now existing in this country. The national investment in reservoirs up to 1940 was at least 5 billion dollars. Thus, the damage figure is equivalent to about 1.0 percent annually of the investment. This should not be taken to imply, however, that the average rate of silting is 1.0 percent. The estimate is based essentially on the annual cost of fully maintaining the services now provided by these reservoirs through construction of additional storage or equivalent facilities as needed, plus the net losses if replacement is not possible. Additional storage must be provided in many drainage areas when 15 to 40 percent of the capacities of existing reservoirs are depleted. Often the supplementary storage will cost 2 to 10 times as much as the initial storage per acre-foot.

(3) Cost of maintenance or progressive impairment of the capital value of drainage enterprises - $17,000,000. Studies of sedimentation in ditches of various drainage districts have led to the conclusion that an average value of 20 cents per acre annually for 86 million acres in drainage enterprises would give a fair measure of damages due to impairment of drainage canals or the cost of maintaining them.

(4) Cost of maintenance of irrigation enterprises - $10,000,000. This is approximately 25 percent of the annual total operation and maintenance charge for irrigation enterprises as reported in the 1940 census. This figure is believed to be on the conservation side.

(5) Cost of maintenance of harbors and navigable channels as a result of sedimentation caused by erosion on watershed areas and stream-bank and channel erosion within rivers, but excluding sedimentation caused by tidal currents in harbors - $12,000,000. This figure is based on 1940 costs obtained from the U. S. Army Engineers Annual Report of that year. The costs chargeable to sediment transported from inland areas have been estimated on the basis of location of the project work.

(6) Cost of water purification as a result of excess turbidity - $5,000,000. This estimate is based on studies of the costs of treatment in representative filter plants, and the amount of turbid water treated annually from surface sources.

(7) Sedimentation damages, partly or wholly included in flood-damage estimates, including increased crop loss due to deposits of sediment on plants, increased damage to property, roads, streets, etc., by costs of cleaning off sediment, increased flood heights due to channel aggradation, at least 20 percent of the minimum estimate of total flood damages, or $20,000 000. This estimate is admittedly based on meager data. It is the estimated difference in damage from a few historic floods with and without the sediment load transported by the flood waters. Flood damages from the Ohio River flood of January 1937 and the southern California flood of 1938, and several others of record, show that a relatively high proportion of the flood damages in urban areas are due to the cost of cleaning sediment from streets, houses, furniture, etc.

(8) Other damages not yet evaluated separately, including the added cost of maintenance of highways, railroads, oil and gas pipe lines, communication lines, damages to power turbines, damages to the fish and oyster industry, damages to wildlife, damages to recreation, and impairment of public health from malaria due to clogging of channels - are believed to total at least $11,000,000, and may be much higher.

If these figures are anywhere near the right order of magnitude, they indicate that engineers and conservationists are confronted with a problem which, in its long-time effects, may have a significance not much, if any, less than flood control. Because the effects of many forms of sedimentation are slowly accumulating, however - because sedimentation is not generally spectacular like a flood, which is here today and gone tomorrow, leaving catastrophe in its wake - the true significance of the sediment problem has not been generally appreciated, even in the engineering profession, much less among laymen.

We are gathered in this conference to explore many of the important aspects of the sediment problem, to hear of the effects of sediment in one form or another, to learn how the problem has been investigated in the field and in the laboratory, and to consider some of the possibilities for remedial action. The problem occurs in so many fields of enterprise that practically every Federal agency concerned with land or water has a direct interest in it. Scores of State and local agencies and engineering firms have evinced much interest in the past few years, and many of them are carrying on constructive investigations now. To the visitors not connected with the Federal agencies, who have come here to learn about and discuss some of these problems with us, I extend a cordial welcome. Your help and interest is not only valued but is essential to the solution of many of the problems with which we are confronted.

We have a crowded schedule for three days. We have purposely not arranged any evening meetings with the thought that many of you would choose to get together in informal groups for discussion of your particular problems. Or maybe you will be simply ready to go to bed after some of these Denver steaks which our hosts tell me about. In any event, I hope your stay here will be profitable and pleasant, worth while professionally, and valuable for the opportunities you will have to talk with your fellow engineers.