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HYDRAULIC RESEARCH  
at  
COLORADO STATE UNIVERSITY  
Summary of Research Projects

Compiled by  
M. M. Skinner  
Assistant Civil Engineer

ENGINEERING RESEARCH  
JUN 1973  
FOOTHILLS RESEARCH ROOM

Engineering Research  
Colorado State University  
Fort Collins, Colorado.

December 1960

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Summary of Research Projects

The summary of each project follows this outline:

- (a) Title
- (b) Sponsors of the project
- (c) Principal investigator
- (d) Type of research, i. e., basic, applied, etc.
- (e) Description of the research
- (f) Present status, i. e., active, suspended, or completed
- (g) Results
- (h) Publications

The outline above follows that used in the Hydraulic Research Bulletin prepared annually by the National Bureau of Standards, U. S. Department of Commerce. The number preceding many of the titles is the NBS number designation.

(55) SNOW COURSE MEASUREMENTS AND FORECAST ANALYSIS.

(b) Soil Conservation Service, Colorado Agricultural Experiment Station.

(c) Jack N. Washichek, Snow Survey Supervisor.

(d) Field investigations; applied research.

(e) Systematic measurements of depth and water content of snow at high elevations in Colorado and New Mexico mountain areas for the purpose of forecasting the runoff of the principal rivers of the state in the interest of irrigation, power, domestic supplies, and other uses. The use of electrical resistance soil moisture units is being tested to determine a factor of soil moisture deficiency for water supply forecast purposes. Most of the major basins now have 2 or more soil moisture stations installed. A period of record must follow before any degree of correlation can be accomplished.

(f) Active.

(g) Forecasts are now being issued at forty gaging stations in Colorado and New Mexico. As forecast procedures improve, more and more vital streams will be forecasted.

(h) Colorado Agricultural Experiment Station General Series Papers --  
Monthly Snow Survey Reports for the Rio Grande, Colorado and Platte-Arkansas Drainage Basin.

Three small basin reports and one two-state bulletin, covering the Rio Grande, Colorado, and Platte-Arkansas drainages are issued monthly, February through May. Supplemental reports are issued January 1, May 15, and June 1.



(821) GROUND-WATER FLUCTUATIONS AND THEIR RELATION TO PUMPING.

- (b) Colorado Agricultural Experiment Station.
- (c) M. M. Skinner, Assistant Civil Engineer.
- (d) Field investigation.
- (e) The work consists of semi-annual measurements of the depth to the water table in about 300 observation wells in the Arkansas and South Platte Valleys in Colorado. The observation wells, a few with continuous recorders, are strategically located in pumping areas. Data on power consumption are also gathered for comparison with water-table elevations. The work is coordinated with the Ground-Water Branch, U.S.G.S.
- (f) Active.
- (g) Water tables continue to generally decline in areas which depend entirely upon ground water for irrigation and have a small natural recharge in comparison to withdrawals. Water tables in the main stem aquifers and areas under canals have recovered quite well following the dry period of the early 1950's.
- (h) "Water Table Fluctuations in Eastern Colorado", by W. E. Code, Colorado State University Agr. Expt. Sta. Bulletin 500-S, 34 pp., August 1958.

(1074) HYDRAULICS OF STILLING BASINS.

- (b) U. S. Bureau of Public Roads.
- (c) G. L. Smith, Assistant Civil Engineer.
- (d) Experimental; applied and fundamental.
- (e) Experimental investigation was made of scour and scour control in an alluvial bed involving outflow from a cantilevered pipe. Scour control was accomplished by means of a pre-shaped basin in the alluvial bed armorplated with graded aggregate. Quantitative tests were limited to rectangular channels with rigid vertical sides but of varying width. A qualitative investigation was scour and scour control in an alluvial channel of trapezoidal cross-section but of one width only. Outflow from the pipe was steady, uniform flow.
- (f) Laboratory tests have been completed. A report covering work to date is being completed.
- (g) Generalized design criteria for an armorplated, pre-shaped stilling basin have been developed. The design criteria are limited to certain flow and sediment characteristics in a rectangular channel with rigid, vertical sides and of a given width. In alluvial channels, armorplating of channel banks is essential to channel stability. In addition, decreasing the slope of the channel banks increases the effectiveness in scour control brought about by the armorplated, pre-shaped basin and banks.
- (h) "Scour and Scour Control Below Cantilevered Culvert Outlets", by G. L. Smith, Colorado State University, Civil Engineering Dept. Report is now in preparation.

"The Manifold Stilling Basin", by G. R. Fiala and M. L. Albertson,  
Colorado State University, Civil Engineering Dept. Report No.  
CER58MLA35.

(1837) SEALING OF IRRIGATION CANALS BY BENTONITE SEDIMENTING.

- (b) Colorado State University Experiment Station, USDA - Agricultural Research Service and Irrigation Districts and Companies.
- (c) R. D. Dirmeyer, Jr., Project Leader, Engineering Research, Colorado State University, Fort Collins, Colorado.
- (d) Applied research and development at field sites, supported by laboratory research where needed.
- (e) Development work with Wyoming high-swell bentonite as a sedimenting agent in sealing irrigation canals is essentially complete. The research and development work is now being concentrated on the use of the low-swell varieties of bentonite as a sedimenting agent for sealing irrigation canals and reservoirs.
- (f) Completed.
- (g) The main advantages of the low-swell bentonite over the high-swell varieties are listed as follows: (1) the low-swell varieties are relatively common in many parts of the Western United States and in other areas of the world, whereas the high-swell bentonites are mainly found in Wyoming, and (2) the chemical character of the low-swell bentonites make them compatible with salty soils and hard waters whereas the high-swell bentonites can undergo objectional physical changes when subjected to such conditions.

(h) "Evaluation Report on Recent Bentonite Sealing Work in Wyoming Canals", by R. D. Dirmeyer, Jr., Colorado State University, Civil Engineering Section, March 1959.

"Testing Bentonite for Sealing Purposes", by R. T. Shen, Colorado State University, Civil Engineering Section, (Colorado Extension Service Circular No. 205 A -- Wyo. Extension Service Circular No. 161).

"Sealing Sandy Ditches with the Bentonite Dispersion Method", by R. T. Shen, Colorado State University, Civil Engineering Section, (Colorado Extension Service Circular No. 202 A -- Wyo. Extension Service Circular No. 158).

"Sealing Rocky Ditches with the Bentonite Multiple-Dam Method", by R. T. Shen, Colorado State University, Civil Engineering Section, (Colorado Extension Service Circular No. 203 A -- Wyo. Extension Service Circular 159).

"Mixing Bentonite for Sealing Purposes", by R. T. Shen, Colorado State University, Civil Engineering Section, (Colorado Extension Service Circular No. 204 A -- Wyo. Extension Service Circular No. 160).

"Sealing Farm Ponds and Reservoirs with Bentonite", by R. T. Shen, Colorado State University, Civil Engineering Section, (Colorado Extension Service Circular No. 206 A -- Wyo. Extension Service Circular No. 162).

"Sediment Sealing of Irrigation Canals," by R. D. Dirmeyer, and R. T. Shen, (Report of three-year period of 1957 through 1959), Colorado State University, Ft. Collins, Colorado. Report No. CER60RDD33, July 1960.

(2066) STUDY OF OPEN CHANNEL CONSTRICTIONS IN A SLOPING FLUME.

- (b) U. S. Bureau of Public Roads.
  - (c) H. K. Liu, Associate Civil Engineer.
  - (d) Experimental; applied.
  - (e) Scour at bridge abutments of various shapes and dimensions have been investigated in the laboratory. Natural sediment having mean sizes of approximately 0.45 mm were used in the tests. Sediment supply of mainly bed load varied from zero to less than 1000 ppm.
  - (f) Laboratory tests have been completed. Data are being analyzed and compiled. A report is currently being written.
  - (g) Criteria for estimating the maximum depth of scour at abutments have been established. The maximum depth of scour, for given sediment size, is found to depend upon the flow depth, velocity, and abutment length and geometry.
  - (h) "Backwater Effects of Bridge Piers and Abutments", by H. K. Liu, J. N. Bradley, and E. J. Plate, Colorado State University, Civil Engineering Section, Fort Collins, Colorado. CER57HKL10.
- "Laboratory Observations of Scour at Bridge Abutments", by H. K. Liu, and M. M. Skinner, Colorado State University, Fort Collins, Colorado. Bulletin No. 242, Highway Research Board. CER59HKL6.



(2277) STUDY OF EVAPORATION FROM SOIL SURFACES IN TERMS OF SOIL AND MICROMETEOROLOGICAL FACTORS.

- (b) Contributing project to Western Regional Project W-32 "Basic Hydrological Factors Relating to Water Conservation".
- (c) Dr. Richard A. Schleusener, Assistant Research Engineer.
- (d) Experimental; Basic research.
- (e) The project is a study of evaporation from soil surfaces. During the past year experiments have been conducted to determine the effect of cyclic variation of ambient conditions of temperature, humidity and radiation on an inverse relation that sometimes exists between the rate of evaporation from a free water surface and the rate of evaporation from a soil in contact with a water table. A study is beginning to determine the effect of gradation, thickness, and soil type on the effectiveness of a gravel mulch for reduction of evaporation.
- (f) Active.
- (g) Under cyclic ambient conditions, the inverse relation between the rate of evaporation from a soil in contact with a water table and that from a free water surface can occur if the ambient conditions are such that the evaporation rate from a free water surface reaches a minimum value that depends on soil type, depth to water table, and may depend on the length of time these ambient conditions exist. The phenomenon does not appear to depend on order of time in which the ambient conditions occur.

Preliminary studies on the characteristics of gravel mulches indicate that as much as 50 to 90 per cent of the moisture lost by evaporation from a soil surface initially saturated can be conserved during the first 3 to 5 days of drying by application of a layer of gravel to the surface.

- (h) "Effect of Depth of Water Table on Evaporation from Fine Sand", M.S. Thesis, by R. W. Staley, Colorado State University, 1957.
- "Factors Affecting Evaporation from Soils in Contact with A Water Table", Ph.D. Dissertation, by Richard A. Schleusener, Colorado State University, 1958.
- "Relations Between Evaporativity and Evaporation from Soils in Contact with a Water Table", by Richard A. Schleusener. A paper presented to the American Meteorological Society Conference on Practical Problems of Modern Meteorology, Denver, 24 September 1958.
- "A Switching Arrangement for Automatic, Remote Temperature Reading", by Richard A. Schleusener, Colorado State University, Agricultural Engineering 40(1):32-33, January 1959. CER58RAS22.
- "The Role of Hysteresis in Reducing Evaporation from Soils in Contact with A Water Table", by Richard A. Schleusener and A. T. Corey. Journal of Geophysical Research 64(4):469-75, April 1959. CER58RAS26.
- "Modification of Bridge Controls to Simulate Diurnal Variation of Temperatures, Humidity, and Radiation. Agric. Eng. 41(7):450-451, July 1960. CER60RAS25.

(2279) LABORATORY AND FIELD STUDY OF THE VORTEX TUBE SAND TRAP.

Cooperative project: Colorado Agricultural Experiment Station and Agricultural Research Service. See U.S. Department of Agriculture, Agricultural Research Service, page 49.

(2513) WATER AND SEDIMENT MEASURING EQUIPMENT FOR EPHEMERAL STREAMS.

(b) Rocky Mountain Forest and Range Experiment Station, Agricultural Research Service and Colorado Agricultural Experiment Station.

(c) A. R. Robinson and A. R. Chamberlain, Colorado State University, Fort Collins, Colorado.

(d) Experimental; applied research.

(e) The present phases of the project are to further develop measuring flumes of trapezoidal shapes for measurement of flows with steep gradients and for a large range of flows.

(f) Active.

(g) Tests of a large 1:2 model have been completed. These tests were made by correlating the results with field measurements and conditions. Upstream approach conditions and flume geometry were made to correspond to the field situation. A number of structures have been constructed and are being observed in the field.

(h) "Trapezoidal Measuring Flumes for Determining Discharges in Steep Ephemeral Streams", by A. R. Robinson, Colorado State

University Research Foundation, Civil Engineering Section,  
Fort Collins, Colorado, Report No. CER59ARR1.

"Model Study of a Trapezoidal Flume for Measurement of Stream  
Discharge", by A. R. Robinson, Colorado State University Research  
Foundation, Civil Engineering Section, Fort Collins, Colorado,  
Report No. CER59ARR57.

(2514) STUDY OF RESISTANCE TO FLOW AND SEDIMENT TRANSPORT IN  
ALLUVIAL CHANNELS.

- (b) U. S. Geological Survey and Colorado State University staff and  
graduate students.
- (c) D. B. Simons, Project Chief, U. S. Geological Survey, Colorado  
State University, Fort Collins, Colorado.
- (d) Experimental and theoretical; basic research (staff, doctoral and  
masters)
- (e) A detailed study of resistance to flow and sediment transport in  
alluvial channels is underway. Bed materials with median dia-  
meters of 0.19 mm, 0.28 mm, 0.45 mm and 0.93 mm are  
being studied.

In addition, the following related investigations are active: (1) A  
study of the effect of fine sediments (clay size) on flow in alluvial  
channels, (2) A study of the effect of temperature on flow in  
alluvial channels, and (3) A study of the effect of gradation size  
of bed material on flow in alluvial channels.

- (f) Active.

- (g) Forms of bed roughness in alluvial channels have been classified. The relation of resistance to flow to forms of bed roughness has been discussed. The effect of change in form of bed roughness on depth-discharge relations for alluvial streams has been described. It has been verified that whether or not ripples form is a function of the size of bed material and that dunes will form irrespective of size of bed material, provided sufficient shear can be exerted on the bed material by the water-sediment complex to cause general motion without having the Froude number equal or exceed unity. The effect of fine sediment (large concentrations of clay) on the apparent viscosity of the water-sediment complex, the fall velocity of the sediment and the effective size of the bed material have been studied. In general, the addition of fine sediment reduces the fall velocity and effective size of the bed material and can cause significant changes in form of bed roughness, resistance to flow, and bed material transport. A preliminary study of effect of temperature change shows that a decrease in temperature will decrease the fall velocity and the effective size of the bed material sufficiently to change form of bed roughness under certain poised conditions. In a sense, the effect of reducing temperature is similar to the effects of adding fine sediment to the water only they are not as significant.
- (h) "A Study of Flow in Alluvial Channels, Water Supply Paper No. 1498a-- Flume Studies Using Medium Sand (0.45 mm) -- in branch of texts, by D. B. Simons and E. V. Richardson.



- "A Study of Flow in Alluvial Channels, Water Supply Paper No. 1498b --  
A Preliminary Investigation of the Effect of Fine Sediment," by  
D. B. Simons, E. V. Richardson and W. L. Haushild. Submitted  
for publication.
- "A Study of Flow in Alluvial Channels, Water Supply Paper No. 1498c --  
Depth-Discharge Relations," by D. B. Simons and E. V. Richardson.  
Submitted for publication.
- "Forms of Bed Roughness in Alluvial Channels," by D. B. Simons  
and E. V. Richardson. Submitted to ASCE for possible publication.
- "A Study of Flow in Alluvial Channels, Water Supply Paper No. 1498d --  
The Effects of Fine Sediment on Fluid Particles, Fall Velocity and  
Flow Phenomenon," by W. L. Haushild, D. B. Simons and E. V.  
Richardson. Submitted for publication.
- "Total Sediment Transport in Alluvial Channels," by R. J. Garde,  
Ph.D. Thesis, Colorado State University, 1959.
- "Total Sediment Transport in Alluvial Channels -- Effect of Fine  
Sediment on the Mechanics of Flow in Alluvial Channels," by  
W. L. Haushild, M.S. Thesis, Colorado State University, 1959.
- "Sediment Transport in Alluvial Channels -- Examination of Bagnold's  
1956 Hypothesis," by E. V. Richardson, M.S. Thesis, Colorado  
State University, 1960.
- "Resistance to Flow in Alluvial Channels," by D. B. Simons and  
E. V. Richardson, ASCE Publication, HY5, May 1960.

(2760) METEOROLOGICAL OBSERVATIONS.

(b) Colorado Agricultural Experiment Station and U. S. Weather Bureau.

(c) Maxwell Parshall, Assistant Professor.

(d) Field investigation.

(e) The work is being done to obtain a precise long-time record of climatological elements. The elements observed are: maximum, minimum and current air temperature, wet and dry bulb temperatures for dew point temperature and relative humidity, soil temperatures at 3, 6, 12, 24, 36 and 72 inches, wind direction and velocity at 65 ft and 15 in. above surface, barometric pressure, evaporation from a free water surface, water temperature at surface (maximum, minimum and current), precipitation, cloud cover, dew and frost.

(f) Continuing.

(g) New extreme values of temperature have been recorded recently. The Long time mean temperature is increasing. Precipitation varies widely with no long time trend apparent.

(h) Summary of 70 years' record of Meteorological data in process of publication.

(2761) A STUDY OF THE ECONOMIC EFFECT OF CONTROLLING WATER USE IN AN AREA WHERE SURFACE AND GROUND-WATER RIGHTS APPLY TO A SINGLE SUPPLY.

(b) Colorado Agricultural Experiment Station and U.S. Department of Agriculture Regional Project W-42. (Revised)

- (c) M. W. Bittinger, Assistant Civil Engineer.
- (d) Field investigation; applied research.
- (e) The engineering phase of this study has as its purpose the determination of the interrelationships of ground water and surface water in an area where both are used for irrigation. An area in the South Platte Valley has been chosen for this study.  
  
The economic phase will be concerned with the implications of various types of legislative controls which may be applied to the situation.
- (f) Active.
- (g) Inflow, outflow data for a reach along the main stem of the South Platte River have been obtained. Partial analysis of this data has been completed indicating where the principal sources of water entering the river occur and under what circumstances and amounts they occur. The amount of pumping of ground water in the valley near the river has been determined and its effect upon the flow estimated. Analytical methods have been developed to compare with field measurements.
- (h) "Colorado Ground Water Problems - Ground Water in Colorado," by M. W. Bittinger, Colorado Agricultural Experiment Station Bulletin 504-S, August 1959. CER59MWB35.  
  
"Colorado Ground Water Problems - Water and the Law," by E. J. Farmer, Colorado Agricultural Experiment Station Bulletin 505-S, January 1960.

"Colorado Ground Water Problems - The Economic Picture," by  
I. F. Davis, Jr., Colorado Agricultural Experiment Station  
Bulletin 506-S, June 1960.

(2769) EVALUATION OF FLOWMETERS FOR THE MARTIN COMPANY,  
DENVER DIVISION.

- (b) The Martin Company, Denver, Colorado.
- (c) Susumu S. Karaki, Assistant Civil Engineer.
- (d) Experimental; applied.
- (e) The purpose of the project was to carry out tests on the dynamic, kinematic and general performance characteristics of various types of flowmeters used in conjunction with the Titan Missile program. The flowmeters considered were the Gulton, Gentile Tube, and Maxson Ultrasonic, impact strain gage, turbine and rotameters. The fluids under consideration were water, liquid oxygen, liquid nitrogen, JP-4 fuel, RP-1 fuel and MIL-0-5606 hydraulic fluid.
- (f) Completed.
- (g) Accuracy and reliability of certain types of flowmeters were found to be dependent upon fluid, flow and geometric characteristics. Changes in certain properties were found to have their effects on the meter calibrations.
- (h) "Evaluation of the Effect of Approach Tubing Size Upon the Calibration of 3/4 inch Turbine Flowmeters," by M. W. Bittinger, Report No. CER57MWB32, November 1957.

- "Evaluation on The Effect of Viscosity on The Calibrations of Several Flowmeters," by Fred Videon, Colorado State University Report No. CER58ARC5.
- "Influence of Elbow Location and Dynamic Viscosity on Turbine Flowmeter Calibrations," by Fred Videon and A. R. Chamberlain, Colorado State University Report No. CER58ARC19.
- "Evaluation of The Performance of the Gulton Ultrasonic, Gentile Tube and Potter Model 6-424 GLMD 5 Flowmeters," by Fred Videon and G. L. Smith, Colorado State University Report No. CER59FV11.
- "Evaluation of the Performance of the Floating Rotor Design Flowmeter Manufactured by the Pottermeter Company," by S. S. Karaki and Fred Videon, Colorado State University Report No. CER59SSK45.
- "Evaluation of the Performance Characteristics of Turbine-Type Flowmeters," by S. S. Karaki, F. Videon and F. Trelease, Colorado State University Report No. CER60SSK14.
- "Evaluation of The Effects of Viscosity on Performance of Turbine-Type Flowmeters," by S. S. Karaki, F. Videon and F. Trelease, Colorado State University Report No. CER60SSK19.
- "The Effects of Bearing Wear and Induced Fluid Rotation on Several Flowmeters," by F. Videon and S. S. Karaki, Colorado State University Report No. CER60SSK20.



"Evaluation of The Performance of Turbine-Type Flowmeters -

A Summary Report," by S. S. Karaki and F. Videon. Colorado State University Report No. CER60SSK21.

(2770) A STUDY OF SHEAR STRESS FLUCTUATIONS AT A LIQUID-SOLID INTERFACE BY MEASUREMENT OF THE ELECTROKINETIC POTENTIAL FLUCTUATIONS.

(b) National Science Foundation.

(c) Dr. J. E. Cermak, Professor Engineering Mechanics and Civil Engineering, Head Aerodynamics Laboratory.

(d) Experimental and theoretical.

(e) Electrokinetic-potential-fluctuation spectra are being measured for a range of electrode spacings and flow regimes in a glass pipe. These data together with auto-correlation data for the electrokinetic potentials will be used to determine the character of shear stress fluctuations at the pipe wall.

(f) Active.

(g) Preliminary electrokinetic-potential-fluctuation spectra show similar energy-frequency distributions as do turbulent velocity fluctuations measured in a turbulent flow near a solid wall.

(h) "Electrokinetic-Potential Fluctuations Produced by Turbulence At A Solid-Liquid Interface," by Gilbert Binder, Ph.D. Dissertation, Colorado State University, September 1960, 121 pp.

(2902) DEVELOPMENT IMPROVEMENT OF WATER MEASURING DEVICES.

Cooperative project: Colorado Agricultural Experiment Station and Agricultural Research Service. See U.S. Department of Agriculture, Agricultural Research Service, page 50.

(3034) DISTRIBUTION AND CONCENTRATION OF RADIOACTIVE WASTES  
IN STREAMS BY FLUVIAL SEDIMENTS.

- (b) U.S. Geological Survey for the Reactor Development Branch of the Atomic Energy Commission.
- (c) D. W. Hubbell, Hydraulic Engineer, U. S. Geological Survey  
c/o Civil Engineering Department, Colorado State University,  
Fort Collins, Colorado.
- (d) Experimental and theoretical research based on both field and laboratory experiments; applied and basic research.
- (e) Natural streams provide a convenient and effective medium for the disposal of low-level radioactive wastes. When radionuclides are introduced in streams they become fixed on sediment particles. As a result, waste disposal depends, in part, on the transport and dispersion of the sediment. Project activity includes field and laboratory studies on the application and development of transport and dispersion theory for bed and suspended load. In addition, some phases of the dispersion of liquid contaminants are being studied.
- (f) Active.
- (g) Preliminary studies of polyethylene particles released from a point source indicate that for dispersion at the water surface of an 8-ft wide alluvial channel having small dunes, transverse distribution of particles follows a normal distribution, and the coefficient of transverse diffusion,  $K$ , in the Fickian theory increases with time and approaches a constant value asymptotically.

- (h) "Progress Report: Dispersion and Concentration of Radioactive Wastes by Stream Sediments," by W. W. Sayre, H. P. Guy, and A. R. Chamberlain, Report No. CER59ARC26.
- (3035) CONSEQUENCES OF RESTRAINT ON MOTIONS OF A MODEL SHIP.
- (b) U. S. Navy, David Taylor Model Basin.
- (c) E. F. Schulz, Associate Civil Engineer.
- (d) Experimental; applied research.
- (e) The purpose of this project is to obtain experimental data on the influence of restraint on the model motions resulting from wave trains acting on a model ship. Initially the model motions will be restrained and the forces and moments on the model caused by the waves will be measured.
- (f) Completed.
- (g) A six component balance was used to measure the forces and moments on the restrained model while being towed at various speeds on different headings. Report is now being prepared.
- (3036) THE LONGITUDINAL DISTRIBUTION OF FORCES AND MOMENTS ON A RESTRAINED MODEL IN WAVES.
- (b) S-3 Panel of Hull Structure Committee, Society of Naval Architects and Marine Engineers.
- (c) E. F. Schulz, Associate Civil Engineer.
- (d) Experimental; applied research.
- (e) The primary objective of this project is to impose pitching and heaving displacements (separately) varying sinusoidally in

time upon a model ship and to measure the forces and moments as a function of time. The models are segmented and attached to an oscillating strongback by means of a stiff spring. The force on each end of the segment is sensed by means of an SR4 strain gage. The simultaneous records of the forces on the seven segments may be used to construct a longitudinal shear curve.

The longitudinal bending moment is found by graphical integration.

- (f) Completed.
  - (g) The pitching and heaving experiments on a five-foot model of a T2-SE-A1 tanker have been completed. The model was oscillated at seven frequencies at rest and at three speeds of advance. The results have been analyzed and were compared with the analytical findings of Haskind.
  - (h) "Longitudinal Distribution of Vertical Mass, Vertical Moment of Inertia, Damping Force and Damping Moment on a Pitching and Heaving Ship," by M. R. Bottaccinni and E. F. Schulz, Report No. CER60EFS32.
- (3037) STUDY OF ATMOSPHERIC SURFACE LAYER PHENOMENA IN A WIND TUNNEL.
- (b) National Science Foundation.
  - (c) Dr. J. E. Cermak, Professor Engineering Mechanics and Civil Engineering and Head Aerodynamics Laboratory.

- (d) Experimental and theoretical; basic research.
  - (e) Measurements of mean velocities and mean temperatures together with turbulence intensities and correlations have been made over a smooth, plane, heated or unheated surface. The objective of the program is to relate the turbulent boundary layer structure to the thermal stratification obtained by heating.
  - (f) Active.
  - (g) Heating of the turbulent boundary layer at low Reynolds number has been found to produce the following effects: (1) increase the coefficient of drag, (2) increase the eddy viscosity, (3) increase the correlation between vertical and horizontal velocity fluctuations.
  - (h) "Turbulent Boundary Layer at Low Reynolds Number with Unstable Density Stratification Produced by Heating," by J. E. Cermak, Ph.D. Dissertation, Cornell University.  
  
"Mean Velocity Profiles for Flow Over a Plane, Smooth, Heated Boundary," by E. N. Earle, M.S. Thesis, Colorado State University, June 1960.
- (3041) MAGNITUDE AND FREQUENCY OF FLOODS FROM SMALL WATERSHEDS IN ARID AND SEMI-ARID AREAS.
- (b) U.S. Bureau of Public Roads.
  - (c) Dr. Richard A. Schleusener, Civil Engineering Department, Colorado State University.
  - (d) Applied research.



- (e) A study was made of factors affecting peak rates of runoff in the semi-arid region of eastern Colorado and adjacent areas for watersheds less than 1000 square miles.
- (f) Completed.
- (g) It was determined from gaged watersheds that peak rates of runoff can be estimated from parameters of watershed area, channel slope, and a soil infiltration index in the region east of the Rocky Mountain foothills. Watershed area, elevation, and geographical location parameters can be used for estimates of peak rates of runoff in the Rocky Mountain foothills. Design charts and procedures are presented for determining peak rates of runoff from ungaged watersheds using the appropriate parameters.
- (h) "Preliminary Report on Magnitude and Frequency of Runoff from Small Watersheds in Arid and Semi-Arid Areas," by Richard A. Schleusener, G. L. Smith, and N. Yotsukura, Civil Engineering Section, Colorado State University Report No. CER59RAS39.
- "Estimates of Runoff from Small Watersheds in Eastern Colorado, Western Kansas and Nebraska, and Southeastern Wyoming," by Richard A. Schleusener, and G. L. Smith, Civil Engineering Section, Colorado State University, Fort Collins, Colorado. Report No. CER59RAS41.

"Study of Peak Rates of Runoff in Eastern Colorado and Adjacent Areas," by Richard A. Schleusener, George L. Smith, and Lewis O. Grant. Colorado State University Report No. CER60RAS31.

"Procedures for Estimating Peak Rates of Runoff in Eastern Colorado and Adjacent Areas," by Richard A. Schleusener, George L. Smith, and Lewis O. Grant. Colorado State University Report No. CER60RAS30.

- (a) THEORY OF CONSOLIDATION COMBINING PRIMARY AND SECONDARY CONSOLIDATION.
- (b) National Science Foundation.
- (c) I. S. Dunn, Associate Professor.
- (d) Experimental and theoretical; basic research.
- (e) The study consists of a mathematical analysis of the effect of viscoplastic resistance on the rate of pore pressure decrease and of an experimental program to verify the mathematical results and to investigate the effect of varied load increments on the time-consolidation relationship. The mathematical analysis will be carried out by adding viscoplastic resistance terms to the basic differential equation of consolidation developed by Terzaghi and solving the resulting equation either by standard methods or by analysis of a theoretical model. The solution of this system along with the laboratory consolidation curves will be used to produce

the relationships between plastic resistance and related variables such as speed of deformation and per cent of deformation.

(f) Active.

(3394) RESEARCH ON ARTIFICIAL AND NATURAL RECHARGE OF GROUND WATER IN COLORADO.

(b) Colorado Agricultural Experiment Station.

(c) M. W. Bittinger, Assistant Civil Engineer.

(d) Experimental and applied research.

(e) The research under this project is being carried out in three major parts. Part I consists of an over-all analysis of the artificial recharge needs and possibilities in seven major ground-water basins in Colorado. This analysis will be based principally upon available information of water supply, water quality, geology, water use and other physical factors. Part II consists of the selection and establishment of field experiments on representative areas within the various ground-water basins. Part III consists of theoretical and laboratory studies to extend the information obtained under Part II.

(f) Active.

(g) Field studies have been established at three sites in the South Platte Basin of Colorado. Studies have been completed at one of these sites, Prospect Valley. Analytical developments have been made to compare with field measurements.

(h) "The Development and Dissipation of a Ground Water Mound Beneath a Spreading Basin," by M. W. Bittinger and F. J. Trelease, presented at the 1960 winter meeting of the American Society of Agricultural Engineers, Memphis, Tenn. Dec. 5-7, 1960  
Colorado State University Report No. CER60MWB50.

(3395) FUNDAMENTAL STUDY OF A SUBMERGED THREE-DIMENSIONAL JET IMPINGING UPON A NORMAL PLANE.

(b) National Science Foundation.

(c) George L. Smith, Assistant Civil Engineer, and J. E. Cermak, Professor Engineering Mechanics and Civil Engineering  
Head of Aerodynamics Laboratory.

(d) Analytical and experimental; basic research and graduate thesis.

(e) An analytical and experimental study is being made of the axisymmetrical flow resulting from an air jet impinging normally on a smooth flat boundary. Measurements of velocity profiles and turbulent intensities are being made in the region of the radial fully developed boundary layer. A shear meter is being designed to measure directly the wall shear stress in order to check the results obtained by means of the momentum integral equation. Experimental data will be used to describe the phenomena of the boundary layer flow.

(f) Active.

(g) Preliminary pressure measurements in the stagnation zone follow closely the pressure distribution as given by irrotational flow

analysis. In the radial fully developed boundary layer flow, data for five runs have been obtained in which the height of the jet orifice was kept constant but the jet diameter and discharge was varied. These data indicate that the mean velocity in the outer region follows a similarity law and that in the inner region the shape of velocity profiles varies slightly with a characteristic Reynolds number.

- (h) "Flow Characteristics of a Circular Submerged Jet Impinging Normally on a Smooth Boundary," by Michael Poreh and J. E. Cermak, Colorado State University, Fort Collins, Colorado. Proceedings - Midwestern Conference on Fluid and Solid Mechanics, The University of Texas, September 9, 1959.

(3397) BHUMIPHOL DAM TUNNEL JUNCTION

- (b) Engineering Consultants, Inc., Denver, Colorado.
- (c) Susumu S. Karaki, Assistant Civil Engineer.
- (d) Experimental; applied research.
- (e) The purpose of this model study was to devise a protective structure within an unlined outlet works tunnel to protect the walls from erosion due to large velocities.
- (f) Completed.

(g) A hydraulic jump stilling basin was developed in the model as a device to reduce the velocities at the tunnel bend. The basin was located immediately downstream from the outlet valves within the circular tunnel. Concrete lining was provided within the basin section to protect against erosion. At maximum discharge the jump completely filled the tunnel and positive pressures were created in the zone upstream from the stilling basin sill.

(h) "Hydraulic Model Study of the Outlet Works for Bhumiphol Dam," by Susumu Karaki. Prepared for Engineering Consultants, Inc., Denver, Colorado. Colorado State University Report No. CER60SSK5.

(3398) WIND TUNNEL MODELING OF ATMOSPHERIC DIFFUSION.

(b) National Institutes of Health.

(c) Dr. J. E. Cermak, Professor Engineering Mechanics and Civil Engineering, and Head Aerodynamics Laboratory.

(d) Experimental and theoretical.

(e) A point source of gas (ammonia) located within a turbulent boundary layer formed by the flow of air over a flat plate is used to create a concentration field downstream of the source. Provisions are also made to heat the boundary from below to produce a boundary layer with unstable density stratification. Sampling of the concentration field is accomplished by drawing measured volumes of gas through water. The solution is then analyzed colorimetrically to determine the methylamine concentration. The concentration fields are being studied in an attempt to determine the effects of

non-isotropic boundary layer turbulence on diffusion.

An attempt will be made to correlate wind-tunnel-diffusion phenomena to diffusion phenomena in the atmospheric surface layer.

- (f) Active.
  - (g) Considerable concentration field data have been obtained for the neutral boundary layer case. Systematic variations of the point-source elevation relative to the local boundary layer thickness is yielding information regarding the relative diffusion rates as a function of position within the boundary layer.
  - (h) Ph.D. Dissertation in preparation.  
"Wind Tunnel Modeling of Atmospheric Diffusion," by J. E. Cermak.  
Paper presented at the Third Air Pollution Research Seminar, New Orleans, La. March 1960. Colorado State University Report No. CER60JEC5.
- (3399) CLIMATOLOGY OF THE UPPER COLORADO RIVER BASIN.
- (b) State of Colorado - Colorado Water Conservation Board.
  - (c) Dr. Richard A. Schleusener, Assistant Research Engineer.
  - (d) Applied research.
  - (e) The research conducted at Colorado State University involves a study of the variability of certain meteorological parameters in the Upper Colorado River Basin, and their relation to stream flow.



The Study at Colorado State University is in cooperation with two other phases being conducted by the University of Colorado, Bureau of Economic Research, and the High Altitude Observatory, respectively. In the other phases of the study, the variability of stream flow in the Upper Colorado River Basin, and the relation of these variations to various upper atmosphere parameters is being investigated.

(f) Active.

(g) Original weather records from 30 stations in the Upper Colorado River Basin for 1283 station-years of record have been transferred to IBM cards. The data are being reduced to storm totals, from which frequency distributions will be derived.

(3400) HYDRAULICS OF SUB-CRITICAL FLOWS IN SMALL, ROUGH CHANNELS.

(b) Colorado Agricultural Experiment Station; U.S. Department of Agriculture, Agricultural Research Service.

(c) Norman A. Evans, Head, Department of Agricultural Engineering, Colorado State University.

(d) Experimental and field investigations;  
Basic and applied, portions will be used for Master's and Doctoral Theses.

(e) This study is an experimental investigation utilizing a tilting flume in which a small channel 60-feet long is formed by natural soil

which is fixed in position against movement by chemical spray. A variety of roughness forms can be created on the bed. A range of channel slope and flow depth are used. Channel shape is a variable.

(f) Active.

(g) An equation was developed relating Chezy's resistance coefficient to the standard deviation of the bed roughness in the longitudinal direction and the Reynold's number. Although there is a clear relationship, the standard deviation is inadequate to fully characterize the bed roughness, and some additional geometrical characterization is still needed. Turbulence has been shown to develop in the shallow flows at very low Reynold's numbers and on the other hand, complete turbulence was not developed in the channel at Reynold's number in excess of 7,000.

(3401) DRAINAGE DESIGN CRITERIA FOR IRRIGATED LANDS.

(b) Colorado Agricultural Experiment Station.

(c) Norman A. Evans, Head Agricultural Engineering Department.

(d) Applied.

(e) A sand tank has been used to study the hydraulics of flow near the drain tile as well as the design criteria for gravel filters for tile drains. Hydraulic characteristics of flow through a gravel-filled mole drain will be studied later as an extension of these studies.

(f) Active.

(3402) DEVELOPMENT OF AN ULTRASONIC STREAM BED ANALYZER.

(b) Agricultural Research Service.

(c) S. S. Karaki, Assistant Civil Engineer.

Earl Gray, Instructor, Electrical Engineering.

(d) Applied.

(e) The research was undertaken to develop an electronic instrument to simultaneously measure the water surface and stream bed profiles in alluvial streams. This instrument is to be used for research into the mechanics of water and sediment flows in alluvial streams at the Agricultural Research Service Laboratory in Oxford, Mississippi.

(f) Completed.

(g) The Dual Channel Stream Monitor, as this instrument has been named, has been successfully developed and tested in the laboratory. Water surface and bed profiles can be mapped accurately under flume conditions.

(h) "Dual Channel Stream Monitor, Final Report to Agricultural Research Service Beltsville, Maryland," by Earl E. Gray and S. S. Karaki. Colorado State University Report No. CER60SSK46.

"Operational Manual for the Dual Channel Stream Monitor," by Earl F. Gray, and S. S. Karaki.

(3403) A **STUDY OF TWO-PHASE, SINGLE COMPONENT FLOW IN A VENTURI.**

- (b) National Bureau of Standards, Boulder, Colorado.
- (c) R. V. Smith, Associate Professor of Mechanical Engineering.
- (d) Experimental and applied.
- (e) Controlled mass flows and vapor-to-liquid ratios of steam and water are run in an instrumented Venturi tube. Pressure and temperatures are recorded at stations along the tube. These data are used in correlations and in preliminary analytical studies.
- (f) Suspended.
- (g) Some correlations have been successful. Preliminary analytical calculations indicate the flow regime is changing through the venturi tube.
- (h) "A Preliminary Study of Steam and Water Flow in Venturi Tubes," by R. V. Smith, P. C. Wergin, J. H. Ferguson and R. B. Jacobs. Submitted to ASME Transactions for publication. Colorado State University Report No. CER60RVS47.

(3404) **PRESSURE DISTRIBUTION FOR TWO-PHASE FLOW IN A TWO-DIMENSIONAL POROUS MEDIA MODEL.**

Cooperative project: Colorado Agricultural Experiment Station and Agricultural Research Service. See U. S. Department of Agriculture, Agricultural Research Service, page 51.

(a) EVALUATION OF HAIL SUPPRESSION

(b) National Science Foundation.

(c) Dr. Richard A. Schleusener, Assistant Research Engineer.

(d) Field investigation; applied research.

(e) Observations were made of the occurrence and intensity of hail in and near a commercial cloud-seeding operation conducted in north-eastern Colorado during the summer of 1959 for the purpose of attempting to reduce hail damage. The distribution of precipitation in the same region was also studied.

(f) Completed.

(g) Simple instrumentation was developed to estimate the intensity of hail fall in terms of impact energy (foot-pounds per square foot). Comparison of impact energies from both seeded and non-seeded cases does not give a clear-cut distinction to evaluate the seeding operation, but does appear to indicate a favorable effect (reduction of hail intensity) in some cases.

Analysis of precipitation anomalies, based on a target-control analysis, shows that nine out of ten storms gave positive anomalies for the "target" stations.

(h) "An Energy Method for Relative Estimates of Hail Intensity," by R. A. Schleusener, and P. C. Jennings. Bull. Amer. Meteor. Soc. 41(7):372-376, 1960. Colorado State University Report No. CER59RAS25.

"A Review of Research on Hail," by Richard A. Schleusener.

Colorado Farm and Home Research 10(2):1-3, May-June 1960.

Colorado State University Report No. CER60RAS26.

"Hailstorm Damage to Crops in Northeastern Colorado, and An Analysis of Precipitation Anomalies Associated With A Cloud-Seeding Program in 1959," by Richard A. Schleusener. Submitted for publication to the Journal of the American Society of Sugar Beet Technologists. Colorado State University Report No. CER60RAS1.

- (a) CHARACTERISTICS AND FORMATION OF HAIL.
- (b) National Science Foundation.
- (c) Dr. Richard A. Schleusener, Assistant Research Engineer.
- (d) Field and laboratory investigation; Basic research.
- (e) The characteristics and formation of hail will be studied through the following steps: (1) Development of suitable instrumentation to determine the characteristics of the hail reaching the ground, (2) establishing a suitable network of observing stations at the ground to determine these characteristics, (3) examination of the clouds from which the hail falls, using visual, photographic, and radar observations, and (4) determining the effects of cloud modification by artificial means. The synoptic environment in which hailstorms occur will be examined.

- (f) Active.
- (g) Instrumentation is being developed for the first phase of the study.

A limited ground network of observing stations was established in the summer of 1960. The work will be continued and expanded in 1961.

- (h) "The 1959 Hail Suppression Program in Colorado and Evidence of its Effectiveness," by Richard A. Schleusener. Submitted for publication in NUBILA. Colorado State University Report No. CER60RAS41.

"The Occurrence and Variability of Ice-Forming Nuclei During The Hail Season in Northeastern Colorado as Measured at 11,300 ft msl at an Upwind Mountain Station," by R. A. Schleusener and L. O. Grant. Submitted for publication in NUBLIA. Colorado State University Report No. CER60LOG42.

- (a) EFFECTS OF CLOUD SEEDING ON SNOWFALL.
- (b) Research Grant from Climax Molybdenum Company and observational assistance by the High Altitude Observatory of the University of Colorado.
- (c) Lewis O. Grant, Assistant Research Engineer.
- (d) Basic and applied.
- (e) This research involves a study of cloud and precipitation characteristics over the Colorado Rockies under different weather situations during winter with and without the supply of artificial nuclei.
- (f) Active.



- (g) Field equipment and procedures for use at high elevations in the Colorado Rockies have been developed. Observations of the daily accumulation of snowfall and snow water content have been made over a large area for seeded and unseeded days. Additional observations have included daily observations of ice nuclei concentrations; the freezing point depression of snow water samples; and photographic observations of snow water samples.
- (a) MEASUREMENT OF ATMOSPHERIC OZONE WITH THE DOBSON SPECTROPHOTOMETER.
- (b) Air Force Cambridge Research Center.
- (c) Dr. Richard A. Schleusener, Civil Engineering Department,  
Colorado State University.
- (d) Basic Research.
- (e) Measurements of the total amount and the vertical distribution of Ozone with height are being made with the Dobson spectrophotometer.
- (f) Active.
- (g) Observations of total ozone and the vertical distribution with height have been made on a regular basis for days when sky conditions have been clear.

- (a) COOPERATIVE RESEARCH ON PEAK RATES OF RUNOFF.
- (b) Department of Highways of the State of Colorado.
- (c) Dr. Richard A. Schleusener, Civil Engineering Department,  
Colorado State University.
- (d) Applied research.
- (e) The effect of soil types and slopes were investigated to determine their importance in estimating the frequency and magnitude of peak rates of runoff from small watersheds in the State of Colorado east of the Continental Divide.
- (f) Completed.
- (g) Relationships between soil types and slope characteristics to peak rates of runoff were established and incorporated into design charts and procedures for determining peak rates of runoff from ungaged watersheds.
- (h) "Procedures for Estimating Peak Rates of Runoff in Eastern Colorado and Adjacent Areas," by Richard A. Schleusener, George L. Smith, and Lewis O. Grant. Colorado State University Report No. CER60RAS30.  
  
"Study of Peak Rates of Runoff in Eastern Colorado and Adjacent Areas," by Richard A. Schleusener, George L. Smith, and Lewis O. Grant. Colorado State University Report No. CER60RAS31.

- (a) ANALYTICAL STUDY OF THE MECHANICS OF SCOUR.
- (b) U. S. Bureau of Public Roads.
- (c) G. L. Smith, Assistant Civil Engineer.
- (d) Theoretical.
- (e) An analytical study was made of the mechanics of scour by both a two-dimensional and three-dimensional jet. Using the rectilinear and cylindrical coordinate system for the two cases, an equation of continuity of mass sediment transport is derived and used in describing mathematically the phenomenon of scour for various boundary conditions. Expressions for distribution of sediment transport along the bed are then derived for each condition. Jet flow impinging on a normal boundary is then analyzed by making the assumption that the Bernoulli Equation is valid in the neighborhood of the stagnation point. Plane, potential flow is considered first, followed by flow of a fluid with viscosity. For flow with viscosity from submerged and non-submerged outlets, expressions for the horizontal velocity and shear distribution along the normal boundary are developed using Bernoulli's theorem and the boundary layer theory of Schlichting and Truckenbrodt.
- (f) Completed.
- (g) Generalized equations for the depth of scour are presented for two conditions of outlets based on a law of open channel flow for

sediment transport of the form given by Shields, and on the developed shear distribution along continuity equation. In particular, the variation of scour depth with respect to time and the final depth of scour are described theoretically in terms of dimensionless parameters. It is then shown that the development of the scour hole with respect to time follows the power law and the logarithmic law for the submerged and non-submerged outlets respectively before the final state is reached. The influence of the angle of the jet is analyzed also, in which expressions for the variation of the depth of scour with respect to time and the final depth of scour are also developed.

- (h) "Analytical Study of the Mechanics of Scour For Three-Dimensional Jet,"  
by Y. Iwagaki, G. L. Smith, and M. L. Albertson, Colorado State University, Civil Engineering Department, Report No. CER60GLS9.
- "Analytical Study of the Mechanics of Scour For Two-Dimensional Jet,"  
by L. Duckstein, Y. Iwagaki, G. L. Smith, and M. L. Albertson,  
Colorado State University, Civil Engineering Department, Report No. CER60GLS12.
- (a) UNSTEADY FLOW IN A STORM DRAIN.
- (b) U.S. Bureau of Public Roads, Division of Hydraulic Research.
- (c) Dr. Vujica M. Yevdjovich, Research Hydraulic Engineer.

- (d) Theoretical; basic research.
- (e) The problem is to study the hydrodynamics of unsteady flow in storm drains with the objective of developing a procedure adapted to a digital computer, verifying the procedure by hydraulic model tests and field measurements as may seem necessary. The ultimate purpose is to provide a working design method applicable to any situation where storm drains are used for removal of stormwater. With the initial and boundary conditions clearly defined for storm drains, the first phase of the research project is concerned with the analytical aspects of the problem.
- (f) Active in the initial stage.
- (g) The analysis of varieties of initial and boundary conditions in storm drains has resulted in adoption of a generalized storm drain, with water inlet points contributing to discharge changes, and junction points contributing to discharge and water level interrelationships of the system of storm drains.
- (a) DEPRESSED CURB OPENING INLET.
- (b) Bureau of Public Roads, Washington, D. C.
- (c) S. S. Karaki, Assistant Civil Engineer.
- (d) Experimental; applied research.
- (e) Design criteria for spacing and sizing of curb inlets on highways varies considerably throughout the country. Under-design as

well as over-design is undesirable and uneconomical. Through a full scale model, criteria for efficient hydraulic design will be developed for the depressed curb opening inlets.

(f) Active.

(a) MECHANICS OF FLOW OF SEDIMENT IN PIPES.

(b) Colorado Agricultural Experiment Station.

(c) N. Yotsukura, Graduate Research Assistant.

S. S. Karaki, Assistant Civil Engineer.

(d) Experimental, basic research.

(e) Studies in open channel flow on the transport characteristics with bentonite in suspension have indicated that the total transport increases as the bentonite concentration in the flow increases. The mechanics of this transport phenomenon is being investigated in a closed recirculating pipe system.

(f) Active.

(a) FLOW CHARACTERISTICS OF LOW WEIR STRUCTURES IN ALLUVIAL CHANNELS .

(b) National Science Foundation.

(c) D. B. Simons, Civil Engineering Department, Colorado State University, Fort Collins, Colorado.

(d) Experimental investigation.

(e) The flow characteristics associated with low weir structures, with sloping upstream and downstream faces, built across alluvial streams have been investigated in a two feet wide, variable-slope,

recirculating laboratory flume.

Two sediments have been used in an attempt to approach the problem of sediment selection for a model to simulate a prototype situation.

The effectiveness of three different sizes of triangular block energy dissipators attached to the downstream slope of the structure has been studied qualitatively.

- (f) Laboratory work has been completed.
- (g) The surface roughness of the model structure affects the discharge coefficient. Water surface level fluctuations, associated with dune movement at an upstream gaging station indicates the desirability of continuous recording of the elevations of the water surface. Upstream dune and ripple patterns are unaffected by the presence of the structure. Velocity of approach must be considered in discharge coefficient determination due to the changing upstream alluvial bed level. Two simulated hydrographs showed that bed configurations at any time is a function of the magnitude, slope and duration of the flood and whether considered on the rising or falling stage.
- (h) Report being prepared.



- (a) DEVELOPMENT AND USE OF COLORADO BENTONITE IN SEALING IRRIGATION CANALS AND RESERVOIRS.
- (b) State of Colorado.
- (c) R. D. Dirmeyer, Jr., Project Leader, Colorado State University, Fort Collins, Colorado.
- (d) Field investigations; applied research and development.
- (e) Work consists of three stages: (1) Inventory of clay deposits in Colorado, with emphasis on those potentially useable in sealing canals and reservoirs; (2) Laboratory evaluations of clays from (1) above; (3) Field trials in canals and reservoirs with best clays found in (1) and (2) above, and evaluation of sealing results, (initial and with time).
- (f) Active.
- (g) The results are discussed by stages as mentioned in (e) above:
- 1 - Inventory -- About 70 favorably appearing deposits have been sampled to date.
  - 2 - Laboratory evaluation -- Satisfactory laboratory test procedures have been developed. Of the 70+ samples from (1) above, about 40 seem worthy of field trial testing.
  - 3 - Field trials -- Preliminary results from about 40 field trials have been obtained. Sealing results range from excellent to poor. Development work is being continued.
- (h) Quarterly Reports available beginning May 1, 1960.

(a) ANALYTICAL STUDY OF LOCAL SCOUR.

(b) U. S. Bureau of Public Roads.

(c) Dr. V. M. Yevdjevich, Research Hydraulic Engineer.

(d) Basic; applied.

(e) The study includes an analysis of existing experimental model data on scour around bridge piers and abutments and at culvert outlets with respect to time. The theoretical analysis of the mechanics of scour will serve as a framework for relating model and prototype results.

(f) Active.

(a) FLOW CONTROL AND MEASUREMENT.

(b) International Boundary and Water Commission, United States Section.

(c) S. S. Karaki, Assistant Civil Engineer.

(d) Experimental; applied research.

(e) Stream flow in the Rio Grande River and certain of its tributaries between Fort Quitman, Texas, and Gulf of Mexico has been difficult to measure because of the changing characteristics of the rivers. Through this study a structure is sought which will stabilize the stage-discharge relationship, specifically at the Del Rio gaging station site. The information obtained from this study should be useful also in designing structures at other stations.

- (f) Active.
- (g) A broad-crested weir has been found to give varying coefficients of discharge with unit discharge and aggradation of the bed upstream from the structure. Slight alterations from the normal broad crest has been found to be beneficial in establishing a stable stage discharge relationship.
- (h) "Field Investigation Report - Locating and Designing Structures to Improve Stream Gaging Accuracy in the Rio Grande River Basin," by the Field Investigation Team - S. S. Karaki, A. R. Chamberlain, D. B. Simons, A. R. Robinson, and M. L. Albertson. Submitted to the International Boundary and Water Commission, El Paso, Texas. Colorado State University Report No. CER60SSK34.  
"Interim Report - Hydraulic Model Studies Del Rio Site Stream Gaging Control Structure (Two Dimensional Studies) ," by S. S. Karaki for International Boundary and Water Commission, United States Section. Colorado State University Report No. CER60SSK62.
- (a) LOW SPEED PRECISION WIND TEST FACILITY.
- (b) White Sands Missile Range, New Mexico.
- (c) Dr. J. E. Cermak, Professor Mechanics and Civil Engineering.
- (d) Developmental; design.
- (e) A low-speed wind tunnel is being designed for use in calibrating and standardizing wind measuring instruments. The test section

will be 4 x 4 x 4 ft in size and will have an air speed range from 1/2 to 70 mph. The variation in air speed for a given setting will not vary by more than  $\pm$  1 per cent in space or time excepting within the boundary layers formed on the walls. Turbulence levels will not exceed 0.2 per cent at any air speed.

(f) Active.

(g) -----

(h) "A Study of Design and Operation of a Low Speed Precision Wind Instrument Test Facility," by E. J. Plate and J. E. Cermak. Interim Report. Colorado State University Report No. CER60EJP58.

(a) INVESTIGATIONS TO DEVELOP WIND TUNNEL TECHNIQUES FOR MEASURING ATMOSPHERIC GASEOUS DIFFUSION IN MODEL VEGETATIVE REGIONS.

(b) Agricultural Research Service, U.S. Department of Agriculture.

(c) Dr. J. E. Cermak, Professor Mechanics and Civil Engineering.

(d) Experimental; basic.

(e) Diffusion of a gas (ammonia) into and out of a model vegetated plane area contributing part of a wind tunnel test section floor is to be studied. Using a test section 80 ft long and 6 x 6 ft in cross-section the turbulent boundary layer in which diffusion occurs will be several times thicker than the vegetation height.

Using the basic equations of fluid mechanics, an attempt will be made to establish criterion for application of the model data to prototype conditions. The criterion developed will be checked using field data being obtained at Cornell University by the Agricultural Research Service.

(f) Active.

(a) MICROMETEOROLOGICAL WIND TUNNEL.

(b) U. S. Army Electronic Proving Ground, Fort Huachuca, Arizona.

(c) Dr. J. E. Cermak, Professor of Mechanics and Civil Engineering.

(d) Developmental; design.

(e) A wind tunnel is being designed and constructed which will permit control of air speed (1-150 mph), air temperature (32-200°F) and relative humidity (5-95 per cent). The 6 x 6 ft square by 80 ft long test section will have provisions for heating and/or cooling about 30 ft of the floor. The facility is being designed to permit detailed study of turbulence and turbulent diffusion under various thermal conditions.

(f) Active.

(a) ; SOME ASPECTS OF FLUCTUATIONS IN ANNUAL RUNOFF IN AND NEAR THE UPPER COLORADO RIVER BASIN.

(b) Colorado Water Conservation Board.

(c) Dr. V. M. Yevdjovich, Research Hydraulic Engineer.

(d) Basic; applied.

(e) This study will cover:

1. Effect of overyear storage in the basin on fluctuations of annual runoff;
2. Fluctuation patterns of annual runoff at some stations in the Colorado River basin and in adjacent river basins;
3. Regional patterns in the sequence of annual runoff, based on the analysis of serial correlation coefficients;
4. Analysis of fluctuations by using the range (difference of previous maximum and minimum of accumulated departures from average annual runoff); and
5. Physical and other explanations of patterns in fluctuations of annual runoff and effective annual precipitation. (Effective annual precipitation is defined as annual precipitation minus annual evapotranspiration for individual water years).

(f) Active.

U. S. D. A.

Agricultural Research Service

(2279) LABORATORY AND FIELD STUDY OF THE VORTEX TUBE SAND TRAP.

- (b) Cooperative project: Colorado Agricultural Experiment Station ,  
Agricultural Research Service and U. S. Department of Agriculture.
- (c) A. R. Robinson, Hydraulics Laboratory, Colorado State University,  
Fort Collins, Colorado.
- (d) Experimental; applied research.
- (e) The study is being made to develop generalized criteria for the design  
of the vortex tube sand trap. The sand trap will be used in  
irrigation and power canals for removal of bed load material.
- (f) Completed.
- (g) Tests indicate that with the proper design, the vortex tube sand trap  
is very effective in the removal of bed load material for sizes  
greater than 0.3 mm. The efficiency of trapping varies with the  
velocity of flow across the tube and the size of material. High  
efficiencies can be maintained even though the amount of flow  
removed by the tube is reduced from 15 to 5 percent. Tubes of  
different shapes seem to operate equally well. However, the  
cross-sectional area and length of tube seem to be critical points  
of design.
- (h) "Vortex Tube Sand Trap," by A. R. Robinson, American Society of  
Civil Engineers, Proceedings of the Irrigation and Drainage  
Division, November, 1960.



(2902) DEVELOPMENT AND IMPROVEMENT OF WATER MEASURING DEVICES.

- (b) Agricultural Research Service, U. S. Department of Agriculture and Colorado Agricultural Experiment Station.
- (c) A. R. Robinson, Hydraulics Laboratory, Colorado State University, Fort Collins, Colorado.
- (d) Experimental; applied research.
- (e) The purpose of this project is to develop new water measuring devices and to improve existing ones for the measurement of irrigation water. Present phases of the project are concerned with development of trapezoidal measuring flumes and evaluation of vane type flow meters and modified Hall flow tubes.
- (f) Active.
- (g) Tests have been made of trapezoidal flumes for a variety of sizes and capacities. The capacities range from 0.02 - 60.0 cfs. In general, the trapezoidal shaped flumes have been found to be superior to rectangular ones from an operational standpoint. Vane-type meters have been studied and their relative accuracy determined over a range of operating conditions.
- (h) "Trapezoidal Flumes for Open Channel Flow Measurement," A. R. Robinson and A. R. Chamberlain, American Society of Agricultural Engineers Transactions, Vol. 3, No. 2, 1960. Colorado State University Report No. CER58ARR39.

(3400) HYDRAULICS OF SUB-CRITICAL FLOWS IN SMALL, ROUGH CHANNELS.

Cooperative project; Colorado Agricultural Experiment Station and Agricultural Research Service. See Colorado State University page 29.

(3404) PRESSURE DISTRIBUTION FOR TWO-PHASE FLOW IN A TWO-DIMENSIONAL POROUS MEDIA MODEL.

(b) Laboratory Project (Agricultural Research Service)

(c) R. H. Brooks, Agricultural Engineer.

(d) Experimental verification of proposed theory; basic research.

(e) The purpose of the project is to determine the water table position

in a sloping porous bed, which has an impermeable lower boundary with the upper boundary exposed to the atmosphere, where increases in the permeability of the porous bed cause the water table to change as the flow moves down the slope. The experimental water tables, as obtained for a number of porous materials, are compared with the theoretical water table position.

(f) Active.

(g) For the simple boundary conditions imposed upon the model, and for the few porous materials studied, the results agree closely with the theory.

(h) Publication in preparation.