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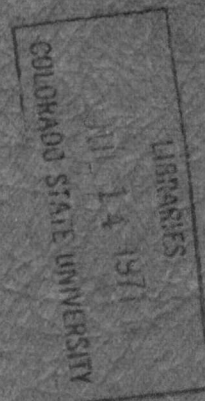
CIVIL ENGINEERING SECTION
COLORADO AGRICULTURAL EXPERIMENT STATION

ANNUAL REPORT

April 25, 1960

by

A. R. Chamberlain



CIVIL ENGINEERING SECTION
COMBATO AGRICULTURAL INTERPRETATION SECTION

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I. ACCOMPLISHMENTS BY PROJECTS

Regular Experiment Station

103 - Laboratory and Field Study of the Vortex Tube Sand Trap: -

This project was essentially completed during the year and the first draft of a report prepared. The results from the study were correlated with those from earlier investigations in order to develop general design criteria for the trap. For the tube to operate successfully the following conditions are necessary.

- (1) The velocity and depth of flow across the section containing the tube should be such that the Froude number approximates 0.8. ($F_r = V/\sqrt{gd}$ where V is the average velocity, g the gravity constant and d the depth of flow.)
- (2) The tube can be a pipe with a portion of the circumference removed to form the opening. The area of tube required can be approximated by the relationship $A_T = 0.06 DL \sin \theta$ where D is the width of opening, L is the length, and θ is the angle of the tube with respect to the direction of flow.
- (3) The width of tube opening (D) should be from 0.5 to 1.0 foot.
- (4) The ratio of L/D should not exceed 20 with the maximum length (L) being approximately 15 feet.

- 4 (5) The angle θ should be 45 degrees.

With the foregoing design specifications, the tube can be expected to remove about 80 percent of the sediment with sizes greater than 0.50 mm. Lower percentages of smaller sizes will be removed. Almost all of the material greater than 1 mm. will be ejected. The amount of flow which will be removed by the operation of the tube will vary from 5 to 15 percent of the total, depending on tube design and depth and velocity across the section. It is necessary to provide a channel or pipe with sufficient gradient to convey the removed flow and material back to a natural channel.

104 - Meteorological Observations: - Climatological observations are taken on a regular schedule twice daily at 7:00 A.M. and 7:00 P.M.

104 - Effects of Cloud Seeding on Snowfall: - Wintertime clouds have been seeded with silver iodide crystals on a random basis in the vicinity of Climax, Colorado. The depth of new snow is measured daily at about 25 locations. Ice nuclei are being counted. Chemical analyses will be made of the precipitation. Comparison will be made of snowfall and ice nuclei between days that were seeded and days that were not seeded. The program ran from 19 February until 1 May 1960.

105 - Groundwater Fluctuations and Their Relation to Pumping: - Spring and fall groundwater level measurements were made in approximately 300 observation wells in eastern Colorado. Water table levels in the observed areas are holding up fairly well where sufficient natural or artificial groundwater recharge is present.

106 - Development and Improvement of Water Measuring Devices: - A number of types and sizes of trapezoidal measuring flumes have been studied and calibrations made. These range in size from small V-notch

flumes, intended primarily for furrow measurement, to one designed for streams with flows up to 400 cfs. Most of these flumes have also been studied and calibrated under submerged conditions.

Advantages which have been noted in using flumes with sloping sidewalls in contrast to the rectangular types are:

- (1) Approach conditions seemed to have a minor effect on the head-discharge relationships.
- (2) Material deposited in the approach section of the flumes did not change materially the relationships.
- (3) A large range of flows can be measured through the structures with a comparatively small change in head. Very small flows can be measured with the same range of accuracy as large ones due to the trapezoidal shape.
- (4) The flumes will operate under greater submergence than rectangular ones of comparable capacity without corrections being necessary to determine the correct discharge.
- (5) The trapezoidal shape fits the common canal section more closely than a rectangular one. Scour problems should be less with this trapezoidal shape.
- (6) Construction details such as transitions and form work are simplified.

At the request of the Soil Conservation Service, orifice plates to be used for measurement of furrow flows were studied. Standard rating tables were developed for both submerged and free flow conditions with the limits for measurement of each type of flow being defined. The effects of upstream approach conditions on the calibrations of the plates were studied and found to exert a minor effect. Also, there was

no discernible effect when the plate was set at angles up to 15 degrees from perpendicular to the direction of flow.

Complete calibration tables as well as instructions for use of orifices ranging in size from 3/4 inch to 4 inches are available in ARS Research Report No. 323.

107 - Hydraulics Laboratory: - A preliminary investigation of super-critical flow confluences was conducted. At the present time there are no known economic methods of building such confluence structures so that culverts, earthwork, ditches, and highways will be adequately protected from such flows overtopping the hydraulic structure.

108 - Sealing of Irrigation Canals by Sedimenting with Colloidal Clays: - Work on development of methods of utilizing a Wyoming high-swell bentonite for sealing of irrigation canals is essentially complete. A rough draft of a Final Three-Year Report of work in this regard is near completion. It will be submitted to a University reading committee within the next few weeks.

109 - Snow Course Measurements and Forecast Analyses: - This work consists of making snow surveys in mountain areas of the state on about 130 snow courses and soil moisture measurements on 30 stations. Water supply outlook based on this information is reported in a formal water conditions and water supply outlook reports during the January 1 - June 1 period. Information is also given to the public by mass media communications.

Three additional small basin reports were issued this year to farmers in the particular area selected. These are being explored as a means of putting forecast information into the hands of all the

runners. These have met with excellent success and it is anticipated that next year the entire state and New Mexico will be covered with this type of report. Several new snow courses have been added this year to supplement the system.

110 - Calibration of Current Meters in Rating Phase: - Current meters have been rated for many municipalities, counties, consulting engineers, and state and federal agencies during the year. This is a service performed at no cost to the Station. A charge of twenty-five dollars (\$25.00) is made for each calibration.

111 - Determination of Proper Irrigation Well Construction Materials and Maintenance Practices of Obtaining Maximum Economical Life and Performance: - Well drillers were consulted as to cause of some well failures and possible preventive measures that may be taken to increase the service life of the well.

112 - Natural and Artificial Recharge of Groundwater: - This project, a study of natural and artificial recharge of groundwater reservoirs in Colorado, was initiated July 1, 1959. The following work has been accomplished:

(1) Classified areas in the South Platte Basin as to needs, possibilities, and feasibility of artificial groundwater recharge.

(2) Established and collected preliminary data from three field studies in the South Platte Basin.

(3) Made a preliminary study of rural public district organizations of Colorado and evaluation as to their adaptability for financing and managing groundwater recharge facilities.

(4) Made preliminary plans for experimental work in artificial recharge in the High Plains area of Colorado.

(5) Entered into agreements with the U.S.G.S. for cooperative work. The Surface Water Branch will operate a stream gaging station on Kiowa Creek to furnish needed information on one of the field studies. The Groundwater Branch will conduct a survey of Colorado municipalities to determine their water needs and possibilities of using groundwater storage to stabilize their supplies.

(6) Made theoretical analyses of groundwater surface water inter-relationships on the South Platte and of the artificial recharge operations in Prospect Valley.

124 - Laboratory Study of Gravel Filter Design for Irrigation Wells: -

The criteria for stability of uniform and non-uniform aquifers and gravel packs were determined by a series of tests in a radial flow model simulating a section of an irrigation well. The test results indicated:

(1) Less aquifer movement occurs with non-uniform gravel packs than with uniform gravel packs at the same pack-aquifer ratio.

(2) At low pack-aquifer ratios, increasing aquifer uniformity decreases initial sand movement.

(3) At high pack-aquifer ratios, increasing aquifer uniformity increases sand movement.

(4) Reversing flow through the model to produce a surging effect reduced head loss at the pack-aquifer interface considerably.

Quantitative values of stable pack-aquifer ratios for uniform and non-uniform materials were determined.

227 - Study of Evaporation from Soil Surfaces in Terms of Soil and Micro-meteorological Factors: - Equipment has been developed to simulate diurnal variation of ambient temperature, relative humidity and radiation in a controlled environment chamber.

Rates of evaporation from soil have been measured under a variety of cyclic conditions.

An inverse relation between rates of evaporation from a free water surface and the rate of evaporation from a soil surface in contact with a water table is produced under certain cyclic conditions. This phenomenon had first been noted in previous work under steady-state conditions.

236 - A Study of the Economic Effect of Controlling Water Use in an Area Where Surface and Groundwater Rights Apply to a Single Supply: -

The majority of the field work under Project 236 was accomplished during the previous fiscal year. However, field measurements of water tables and river discharges were made during the current year to supplement the past data. Analysis of the data is continuing. The pertinent hydrologic data for the past thirty years for the study area has been punched on IBM cards and will soon be analyzed for the correlations of groundwater and surface water relationships. Since this is thought of as a pilot study applicable to many similar areas in other parts of the South Platte and Arkansas Basins, all possible information will be gleaned from the historical data to determine the best procedures and techniques in analyzing the past records.

Colorado State University Research Foundation Projects

724 - Investigations of Contracted Openings in an Open Channel: -

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.

740 - Mechanics of Flow in Alluvial Channels: - Regimes of flow, forms of bed roughness, resistance to flow relations, and sediment transport relations have been developed for the three sizes of sand investigated.

740-C - Distribution and Concentration of Radio Active Waste in Alluvial Streams: - In the first phase, the factors involved and the present status of research concerning disposal of radioactive wastes in streams are reviewed with respect to: (1) waste characteristics, (2) dispersion theory, (3) sorption by sediments, and (4) sediment transport. Sorption of radioccontaminants by sediments is the rule rather than the exception. Sorption, transport, and distribution of radioccontaminants by sediments depend on a multiplicity of factors, many of which are very complex and only partially understood. The second phase is in its initial phase, and no results as yet have been achieved.

747 - Water and Sediment Measuring Equipment for Ephemeral Streams: -

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. Model results have been compared with prototype measurements with good agreement. A large 1:2 model has been constructed and is presently being tested to better determine the operating characteristics of the prototype structure.

761 - Calibration of a Turbinometer for the Martin Company: -

This project is conducted as a service for the Martin Company of Denver, Colorado. Basically the service provides for calibrations of various flowmeters used to measure hydraulic and cryogenic fluid flow for the Titan Missile Program. The project was undertaken in 1957 and has continued to date by annual renewal of the basic contract. The present contract ends in November 1960.

785 - Spur Dikes: - The study of spur dikes for highway bridge protection was started in the previous year and has continued into this fiscal year. The sponsor for this study was the U. S. Department of Commerce, Bureau of Public Roads. This project was completed in September 1959, the results were written formally in a published report to the Bureau of Public Roads and also presented orally by the project leader at the annual meeting of the Highway Research Board in Washington, D. C. in January 1960.

The purpose of the study was to determine the relative benefits of a spur dike to retard or reduce scour at bridge abutments and pier foundations. Extensive experimentation was conducted in the Hydraulic Laboratory in a wide flume for a variety of conditions which simulated field conditions. This research resulted in certain basic recommendations and design considerations for spur dikes. The effectiveness of spur dikes was qualitatively demonstrated and more important, although the objectives of the current research were fulfilled, the study definitely indicated the need for additional research.

2002 - Model Study of Dillon Dam Spillway: - The study of the Morning Glory Spillway for the Dillon Dam was conducted for the consulting engineering firm of Hixton and Kalmbach, Inc., of Denver. Dillon Dam is a municipal waterworks project for the city of Denver. The study was started in the previous fiscal year and completed in August 1959 with a written report to the sponsor.

The purpose of the model study was to develop through experimentation, an efficient morning glory spillway structure which was hydraulically adequate and economically feasible to construct. Through extensive study by means of a hydraulic model, these objectives were accomplished. The recommended structure developed in the Hydraulics Laboratory will be an integral part of the Dillon Dam near Dillon, Colorado.

Much of the original design was modified. The approach section to the spillway was altered by the addition of spillway piers to guide the flow. Means were provided whereby negative pressures that could cause structural damage were changed to positive pressures. The tunnel junction alignments were changed to allow efficient merging of two streams of flow at supercritical velocities, and the energy dissipator was developed to adequately control the entire range of flows.

2003 - Bhumiphol Outlet Works Tunnel: - Control of high velocity flow in a circular conduit was the object of this model study. The study was conducted for the consulting firm of Engineering Consultants, Inc., of Denver, Colorado. The tunnel is a part of the Bhumiphol Dam of the Yankee Project in Thailand for irrigation, flood control, and hydroelectric power development.

The problem was to control the high velocity flow from two high pressure gates to avoid erosion and destruction of a 13.5 meter diameter unlined tunnel. The problem was resolved in the laboratory with the development of an impact-type sill or wall which created an enclosed hydraulic jump stilling pool. The energy was thus converted to greater water depth and heat, and since tranquil flow resulted after the stilling basin, no erosion was to be expected in a rock-lined tunnel. The project was completed in March 1960.

2201 - Martin Company Evaluation: - In this study various flowmeters were evaluated for performance characteristics. Studies were made to determine the effects of various fluid and flow properties on meter accuracy and reliability. Most of the studies were conducted with turbine-type flowmeters, with a limited amount of experimentation also conducted with the Gentile Tube. The study was completed in March 1960 and all the results of the studies are contained in formal reports written and submitted to the sponsor.

2204 - Pitot Tube Calibrations: - This was a short duration project started and completed in March 1960. The nature of this project was to provide service to the Martin Company of Denver for calibrating pitot tubes to be used as flowmeters for rapid loading of liquid oxygen fuel into the tanks of the Titan Missile at the Vandenberg launching site. Along with the routine calibration, a complete engineering analysis was made for converting water calibrations, as performed in the Hydraulics Laboratory for use with liquid oxygen at -270° F temperatures.

2400 - Magnitude and Frequency of Floods in Arid and Semi-Arid Areas: - Procedures have been developed for prediction of peak rates of

runoff from ungaged watersheds for 10 and 100-year recurrence intervals for a region in eastern Colorado and adjoining areas.

2406 - Wind Tunnel Modeling of Atmospheric Diffusion: - A point source of gas (monomethylamine) 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 concentrations. 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.

2409 - Development of a Dual-Channel Stream Monitor Sensor: - The project began March 1959 and is continuing through this fiscal year. The project consists of developing a dual-channel ultrasonic stream monitor for the Agricultural Research Service for use in both laboratory and field for research on the mechanics of alluvial streams. The instrument has been packaged and static tests have been conducted with good results. Tests under dynamic conditions have not begun but are anticipated this fiscal year in the Hydraulics Laboratory.

2425 - Climatology of the Upper Colorado River Basin: - The phase of 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 High Altitude Observatory, respectively. In the phase conducted by the Bureau of Economic Research a study is being made of the variability of stream flow of the Colorado River. In the phase being conducted by the High Altitude Observatory, the effect of solar variability on the general circulation of the atmosphere and on observed weather is being studied.

2426 - Fundamental Study of a Submerged and Non-Submerged Three-Dimensional Jet Impinging Upon a Normal Plane: - An experimental study of the axi-symmetrical flow resulting from a jet impinging on a solid boundary. Detailed measurements will be made of the turbulent structure within the boundary layer as well as direct measurements of the boundary shear stress. The data will be used to determine the nature of the boundary layer development and to check the determination of the boundary shear stress by means of the momentum integral equation.

2442 - Evaluation of Orifice Plates for Measuring Feedwater Flow in Atomic Reactors for Ships: - The project was started in April 1960 and experimentation is currently underway. Early indications are that for accurate flow measurement, the setting of the orifice plate becomes quite critical. Minor geometric changes and alignment seem to have great effect on the differential head measured across the orifice plate.

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III. PUBLIC SERVICES

Maxwell Parrshall prepared weather information which was released regularly to the press and radio. The observations expand a climatological record which began in 1887.

R. D. Birneyer provided program on bentonite canal sealing work for several annual meetings of S.C.S. districts. Also met with several irrigation district boards to discuss bentonite sealing work. He assisted the S.C.S. in setting up jobs for cost-sharing on bentonite sealing work in Colorado Agricultural Conservation Program.

M. W. Bittinger served as Vice Chairman of the American Society of Agricultural Engineers Committee concerned with developing minimum standards for irrigation well construction. He served as program chairman for the Fort Collins Engineers' Club. He made several tape recordings through Colorado State University Information Service for distribution to radio stations on subjects of groundwater and groundwater research. At the request of the Colorado Director of Natural Resources and the State Engineer, he provided technical advice and attended meetings concerned with the groundwater pollution problems in the vicinity of the Rocky Mountain Arsenal.

Mr. Bittinger arranged for several interested people in the groundwater field in Colorado to attend a groundwater recharge conference and tour recharge facilities in California. Men attending included personnel from the State Engineers Office, from the Colorado Groundwater Commission and a State Senator. He organized a short course for water well contractors and others interested in the groundwater field in Colorado. (Held June 19-20, 1959). He worked closely with such state groups as the Colorado Groundwater Commission, the Colorado Water

Conservation Board and the Colorado Director of Natural Resources as well as federal agencies such as the U. S. Geological Survey, the Soil Conservation Service, and the Bureau of Reclamation.

A. R. Robinson supplied a considerable amount of information relating to irrigation and drainage upon request to personnel of the Agricultural Research Service, Soil Conservation Service and State Experiment Station as well as Extension Service. A great deal of this has been from other states. Research results have been presented at Fort Collins, Denver, Salt Lake City, Utah and Reno, Nevada. These have been ARS, SCS and Experiment Station Review Conferences or Workshops. Papers on irrigation structures were presented at two sub-committee meetings of the Colorado Agricultural Planning Committee. A talk on water measurement was given before a meeting of the Rocky Mountain Section, American Society of Agricultural Engineers at New Mexico State University.

Membership on committees or offices held during the year are: to January 1, 1960, President of the Fort Collins Engineers Club; from April 1, 1960, Vice-chairman of the Rocky Mountain Section, American Society of Agricultural Engineers; member of American Society of Civil Engineers Committee on Re-Use of Irrigation Water.

A. R. Chamberlain has given talks and lectures to many civic groups during the last year. He is Director of the Rocky Mountain Cystic Fibrosis Association (Public Health oriented). He has been involved in the work and organization of ARMU, Industrial Development Council Research Committee, Panel discussion groups, etc. He serves on an advisory committee for the USDA-Forest Service Unit serving the western states and two professional task force research groups.

IV. RECOMMENDATIONS

A. The principal recommendation as far as Civil Engineering is concerned is that every effort should be made to induce the State Legislature, private industry, and individuals to make available to the University more nearly adequate funds for expenses and capital investment in equipment. At the present time, with Experiment Station expense accounts essentially being held constant and no Station monies available for capital investment, it is impossible to conduct Station research in a satisfactory manner in the face of continually rising expense costs and the continuous aging of presently available equipment. As an absolute minimum funds should be found to offset the rising costs of expenses incurred in research and to replace worn out equipment. In addition to the needs for capital investment, funds are needed to employ additional semi-professional assistants. At the present time the output of our professional employees is considerably less than it could be if they had adequate semi-professional help.

B. It is felt that this Section is in need of not only monies for the things mentioned above, but from the management viewpoint a redistribution of financial support. At the present time the Section obtains over 80 percent of its budget from non-experiment station sources. This is a dangerously high percentage, which should be reduced to not over 50 percent including salaries by increased allocation of Station monies to the Section.

As a corollary recommendation, CSU engineers should be enrolled to work for Colorado, rather than California, Wyoming, Nebraska and the federal government as they now do during 80 percent of their time. This can only be made possible by more Station funds being given to Engineering.

6. The following are specific recommendations from staff members:

1. Provision of adequate storage facilities for satisfactory maintenance of weather records on IBM cards for use in climatological studies.
2. More communication and coordination of lower levels would help make employees more aware of total function and activities of Experiment Station.
3. Improve telephone facilities.
4. Need volumetric tank in east half of Hydraulics Lab.
5. Purchase good quality lighting system for photography in Hydraulics Laboratory.
6. Provide storage bins for sand.
7. Install water coolers or better for Hydraulics Laboratory offices.
8. Minutes of all CSURF meetings should be written and distributed to faculty just as Faculty Council minutes are distributed.
9. Plans should be made for financing a highly trained and experienced electronics engineer whose only job would be to design and assist in operation of electronic instrumentation, data recording and electronic data analysis. (Proposed salary \$15,000 - 12 months).
10. The anticipated research on tranquil flows in small, rough channels would be facilitated by a closed recirculation system for the 4-foot laboratory flume. With the present hydraulic laboratory piping system, it is not always possible to run the 4-foot flume at the full range of desired discharges when other flumes are being used. A closed recirculation system would correct this limitation. The return system should be designed to handle sediment laden as well as clear water.

11. It is recommended that additional funds be made available to support one half-time graduate assistant for duties with approved Experiment Station projects.

12. Continued expansion is needed in groundwater research due to urgency of complex problems to be solved.

13. Equipment needs are high - the few items owned by Experiment Station are old -- most of the equipment presently in use is borrowed from various agencies.

14. We have an acute need for a good theoretical man to help get our report analysis on a more sophisticated plane.

15. We need to get our wave basin facility indoors so that we are no longer at the mercy of the weather.

16. We need to develop a definite and coordinated plan of action to better acquaint the people of Colorado of the advantages of a more comprehensive program of engineering research -- possibly through an Engineering Experiment Station at CSU.

Respectfully submitted,

A. R. Chamberlain

A. R. Chamberlain, Chief
Civil Engineering Section and
Chief, Engineering Research