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ANALYSIS OF SMALL
WATER MANAGEMENT STRUCTURES
IN IRRIGATION DISTRIBUTION SYSTEMS

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Summary technical completion report prepared for

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Utah State University

by

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Bifurcations and convergences--The principles for separating flow into two or more branches, each carrying some percentage of the original stream, should be determined. Converging flows pose similar problems especially when the flows are at different velocities and head losses must be held to a minimum.

Inlet and outlet transitions--Information is needed concerning the design of transitions to obtain both maximum and minimum head losses.

High velocity canals--More information is needed to predict flow at turnouts, transitions, siphons, curves and other structures when the flow velocity is supercritical.

Canal bank erosion by wind-generated waves--Methods for determining the stable slope of various soil materials when subjected to wave action requires study. Relationships between various exposures, climate, site conditions, and the size of the waves generated need investigation.

Wave suppressors--New and more effective methods should be developed for the elimination of surges and waves in canals.

Seepage meters--Devices are needed to locate seepage areas in canals and to determine the amount of the seepage loss.

Canal sealants--New, low-cost, effective, and durable sealants to prevent seepage losses need development.

Underdrains--Jam-proof flap valves to relieve pressure under linings are needed. New types of valves should be considered.

Sediment control devices--Devices for excluding sediment from canals and pipelines or to keep sediment in suspension throughout the system, should be investigated.

Moss and/or weed elimination devices--Self-cleaning devices for moss and weed elimination are needed.

Riprap--The sizes needed for protection from high velocities and waves should be determined. The most effective way to place riprap should be studied.

Rescue and safety devices--High velocity inlets and steep sided canals can provide hazards for humans and animals. Consideration should be given to rescue and safety devices which will effectively save lives and yet not interfere with the conveyance of the water.

Automatic flow controls--Devices to automatically control flows should be developed. Hydraulic and operational characteristics of both presently available and new equipment must be determined.

In discussing possible means of having the recommended research accomplished, it was suggested by some panel members that a considerable portion of the research material could be undertaken by graduate students, particularly at the Master of Science level. Much of the research suggested at the conference could be more readily accomplished if the topics were identified with specific details and separated into segments in order that an individual graduate student could investigate a single segment.

Considerable literature exists throughout the world regarding small water management structures; however, much of the literature is concerned with particular structures for special uses rather than information of a general nature. The material of a general nature is scattered in numerous laboratory and project reports or design manuals. Because of the cost of an individual small structure, general rules-of-thumb and large factors of safety have been used in design and construction rather than to develop

Examples of such structures are the broken-back transition, manifold stilling basin, USBR stilling basin VI, and USU stilling basin. There is still room for additional thinking regarding such structures. A number of possibilities exist for dissipating energy in the vertical direction, wherein the jet issuing from the closed conduit is either moving vertically upward or vertically downward. In either case, ideas can be borrowed from overflow stands, alfalfa valves, energy dissipator pipe as used in the USU stilling basin deflector plates, slotted plates, slotted caps (e. g. well screens), blocks, and wave suppressors. The design should vary with the amount of excess energy that must be dissipated.

Trapezoidal Baffled Aprons

The U. S. Bureau of Reclamation (Peterka, 1964) has developed design criteria for baffled aprons in rectangular channels. For small structures, it is frequently desirable to use trapezoidal cross-sections. Therefore, design criteria should be developed for trapezoidal baffled aprons. In particular, emphasis should be given to smaller drops, say less than 10 feet. The slope of the trapezoidal walls should be varied from 1:1 to 3:1 (3 horizontal to 1 vertical).

Outlet Transitions

In most cases, the design of outlet transitions in irrigation distribution systems involves reducing the velocity of flow in a short distance and protection against scour if discharging into an unlined

geometry of the approach channel, must be taken into account in these studies.

Debris and Sediment Controls

The removal of objectionable debris and silt from irrigation flows has in the past been largely a problem of devising a mechanical system that will serve the purpose. As a result of this work, several useful designs have been developed, however, they do not meet all the requirements for certain important situations.

Silt and sediment removal techniques for removing bed load from flows have been illustrated by Carlson and Enger (1963) and Dominy (1964). To add to existing design information, a study of the most effective location for positioning the canal turnout as a method to lowering sediment content would be useful. Since the concentration of silt or sediment in the flow increases with depth, positioning the turnout higher up in the flow would serve to lower the concentration in the lateral and add grade to the farmers lateral system.

Debris such as weeds often cause damage to canal and lateral systems in the spring when water is first turned in because of such problems as plugged culverts, fence line obstructions, or clogged headgates. Design information on a portable trash collector could be very beneficial to farmers and ditch riders.

The small trash screens reported by Pugh and Evans (1964) have worked well in most instances, but work could be done to add

design data to allow proper design and construction. For example, the discharge characteristics of these screens for conditions of clogging could be studied, or the effect that certain types of debris such as moss or leaves have on the amount of water passing through the screen. Answers to questions such as these would provide helpful information to individuals designing and building this type of structure.

Tilted Flumes

A very common problem with field installations of flow measuring flumes is that settlement occurs on the downstream end. For such a condition, the value of discharge obtained from the rating curves or tables is less than the true discharge. The only satisfactory solutions, to date, for this problem include: raising the lower end of the flume so it is again level; placing a new level floor in the flume; or placing a liner in the existing flume and then grouting it into place. Normally, when settlement occurs it is not corrected. Therefore, a more satisfactory solution to the problem would be in determining corrections to the rating curves or tables.

Studies are needed to evaluate the effect of slope on the discharge ratings of various types of flow measuring devices. The effect of slope on both the free flow and submerged flow ratings of Parshall flumes, trapezoidal flumes, and cutthroat flumes should be determined.

Also, the effect of sideways tilt on the discharge ratings should be evaluated for each of these flumes.

Approach Velocity

Very little quantitative information is available regarding the effect of approach velocity on discharge ratings of flow measurement structures. Usually, the effect of approach velocity is considered negligible. Yet, numerous examples can be found in the field where high approach velocities are affecting the discharge passing through a rated constriction. If very high approach velocities were encountered, it is not difficult to visualize a profound effect on a rated structure. Consequently, although low approach velocities may have very little influence, there is a quantitative effect as the approach velocity is increased. Therefore, a quantitative evaluation of the relationship between approach velocity and the discharge rating of any particular flow measure device is very important.

Initial studies should determine the effect of approach velocity on a sluice gate, weir, and flow measuring flume. The results from these studies would then show which structures should be fully evaluated for all sizes of the particular structure. Any studies regarding flow measuring flumes should be correlated with the effects of downstream settlement for such flumes.

Siphons

Most siphons consist only of a curved length of constant diameter tubing. Although a few accessories are presently available for alleviating debris and erosion problems, there are undoubtedly a number of improvements which could be made. For example, modifications to the inlet, such as a bell-mouthed shape or hood inlet, might materially improve the hydraulic characteristics of a siphon. Any modifications to siphon inlets should incorporate some form of screening to prevent debris from entering the siphon. Also, there is considerable opportunity for adding various appurtenances to the siphon outlet to prevent erosion.

Prefabricated Structures

Small irrigation structures constructed of concrete and used for water measurement or control are usually cast-in-place. Prefabrication of multiple parts for assembly in the field would be advantageous in the following ways: (1) The unit cost of each installation would be reduced because of savings in time, equipment transport, and materials; (2) Maintenance and replacement would be simpler and longer lasting; and (3) The prefabrication would provide year-round employment for irrigation company personnel.

The information regarding the structural design and methods of assembly must be obtained before a prefabrication operation

can be effective. The structural design should include determinations on adequate thicknesses and reinforcing requirements for the different components of various structures. The assembly techniques for construction of the numerous types of structures that lend themselves to prefabrication should be studied, and the possibility of interchangeable parts in multiple-structure types should be considered.

BIBLIOGRAPHY

- Ackers, Peter. 1958. Resistance of fluids flowing in channels and pipes. Hydraulics Research Paper No. 1. Department of Scientific and Industrial Research, Hydraulics Research Station, Wallingford, Berkshire, England.
- Ackers, Peter. 1963a. Charts for the hydraulic design of channels and pipes. Hydraulics Research Paper No. 2. Department of Scientific and Industrial Research, Hydraulics Research Station, Wallingford, Berkshire, England.
- Ackers, Peter. 1963b. Tables for the hydraulic design of storm-drains, sewers and pipe-lines. Hydraulics Research Paper No. 4. Department of Scientific and Industrial Research, Hydraulics Research Station, Wallingford, Berkshire, England.
- Ackers, Peter, and A.J.M. Harrison. 1963. Critical-depth flumes for flow measurement in open channels. Hydraulics Research Paper No. 5, Department of Scientific and Industrial Research, Hydraulics Research Station, Wallingford, Berkshire, England.
- American Iron and Steel Institute. 1967. Handbook of steel drainage and highway construction products. American Iron and Steel Institute, New York. 368 p.
- American Society of Civil Engineers. 1968. Automation of irrigation and drainage systems. National Irrigation and Drainage Specialty Conference, Phoenix, Arizona. November.
- American Society of Civil Engineers. 1964. Irrigation and Drainage Research Conference. Journal of the Irrigation and Drainage Division. Vol. 90. No IR4. March.
- Anonymous. 1936. The maximum permissible mean velocity in open channels. *Gedrotekhnecheskoe Stroitelstov*.
- Bassett, D.L., and V.E. Hansen. 1964. The discharge coefficient in the coordinate equation for measuring water flow from horizontal pipes. Transactions, American Society of Agricultural Engineers. 7(3):207-208.

- Bata, Geza, Slavoljub Jovanovic, and Vojislav Vukmirovic. 1963. Nomographs for hydraulic computation. Trans., Jaroslav Cerni Institute for Development of Water Resources, Vol. X No. 28.
- Bergstrom, W. 1961. Weed seed screens for irrigation systems. PNW Bulletin 43, Extension Service, Washington State University, Pullman. March.
- Blaisdell, Fred W. 1958a. Hydraulics of closed conduit spillways, Part 1, Theory and its application. Tech. Paper 12, Series B. St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minn.
- Blaisdell, Fred W. 1958b. Hydraulics of closed conduit spillways, Parts 2 through 7, Results of tests on several forms of the spillway. Tech. Paper 18, Series B. St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minn.
- Blaisdell, Fred W. 1958c. Hydraulics of closed conduit spillways, Part 8, Miscellaneous laboratory tests, Part 9, Field tests. Tech. Paper 19, Series B. St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minn.
- Blaisdell, Fred W., and Charles A. Donnelly. 1951. Hydraulic design of the box inlet drop spillway. SCS-TP-106. U.S. Department of Agriculture, Soil Conservation Service, in cooperation with Minnesota Agricultural Experiment Station and St. Anthony Falls Hydraulic Laboratory. U.S. Printing Office, Washington, D.C.
- Blaisdell, F. W. and C. A. Donnelly. 1956. The box inlet drop spillway and its outlet. Trans., ASCE, 121:955.
- Blaisdell, Fred W., and Charles A. Donnelly. 1958. Hydraulics of closed conduit spillways, Part 10, The hood inlet. Tech. Paper 20, Series B. St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minn.
- Blaisdell, Fred W., and Charles A. Donnelly. 1966. Hydraulic design of the box-inlet drop spillway. Agricultural Handbook No. 301. U.S. Department of Agriculture, Agricultural Research Service, in cooperation with Minnesota Agricultural Experiment Station and St. Anthony Falls Hydraulic Laboratory, University of Minnesota. U.S. Printing Office, Washington, D.C.

- Bondurant, J. A., and A. S. Humpherys. 1962. Surface irrigation through automatic control. *Agricultural Engineering*, 43(1):20-21, 35. January.
- Brooks, R. H. 1962. A laboratory evaluation of flow-measurement devices for use in drain tiles. Report CER62RHB71, Colorado State University, Fort Collins, in cooperation with the Northern Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture.
- Buzzard, William. (No date) Flow meter orifice sizing. Handbook No. 10B9000, Fischer and Porter Co., Warminster, Pa.
- Carlson & Enger. 1963. Sediment control at a headworks using guide vanes. A paper presented at the Federal Inter-agency Sedimentation Conference, Jackson, Mississippi. January 28-February 1.
- Carstens, M. R. 1951. The hydraulics of sprinkler irrigation systems. Bulletin No. 212, Institute of Technology, Washington State University, Pullman.
- Cates, Walter H. 1960. Welded steel water pipe manual. Consolidated Western Steel, Division of United States Steel. 106 p.
- Code, W. E. 1961. Farm irrigation structures. Bulletin 496-S. Experiment Station, Colorado State University, Fort Collins.
- Coulthard, T. L., et al. 1959. Screening irrigation water. B. A. E. 6. British Columbia Department of Agriculture, Agricultural Engineering Division.
- Curry, Albert S. 1927. Irrigation structures and implements. New Mexico Extension Circular 92. New Mexico College of Agriculture and Mechanic Arts, Agricultural Extension Service. February
- Dominy, Floyd E. 1964. Design considerations in the economic handling of sediment in irrigation systems. Paper presented at joint meeting of the U.S. National Committee of the International Commission of Irrigation and Drainage and the Irrigation and Drainage Division of the American Society of Civil Engineers, El Paso, Texas. Dec. 2-4.
- Donnelly, C. A., and F. W. Blaisdell. 1965. Straight drop spillway stilling basin. Proc., *Journal of the Hydraulics Division, ASCE*, 91(HY3): 101-131. Paper 4328. May.

- Dusenberry, H. L., and O. W. Monson. 1951. Irrigation structures and equipment. Bulletin 180. Extension Service, Montana State College, Bozeman, Montana.
- Dylla, A. S., M. B. Rollins, and V. I. Myers. 1963. Experimental plastic drains in Nevada. Bulletin 228. Agricultural Experiment Station, Max C. Fleishmann, College of Agriculture, University of Nevada, and Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture.
- Elevatorski, Edward A. 1959. Hydraulic energy dissipators. Engineering Societies Monographs. McGraw-Hill Book Co., New York. 214 p.
- El-Madani, M. 1957. Sand screens at canal intakes. International Commission of Irrigation and Drainage, Annual Bulletin. pp. 49-51.
- Evans, Norman A., and Harold R. Duke. 1963. Water measurement with U. S. Steel irrigation gates. Colorado State University, Fort Collins. October.
- Fair, Gordon Maskew, and John Charles Geyer. 1958. Elements of water supply and waste water disposal. John Wiley and Sons, Inc., N. Y. 615 p.
- Fiala, G. R. 1957. Laboratory study of a manifold stilling basin. Unpublished M. S. Thesis, Colorado State University, Fort Collins, Colorado. May.
- Fiala, Gene R., and Maurice L. Albertson. 1958. The manifold stilling basin. Department of Civil Engineering, Colorado State University Research Foundation, Fort Collins. October.
- Fiala, G. R., and M. L. Albertson. 1961. Manifold stilling basin. Proc., Journal of the Hydraulics Division, ASCE, 87(HY4):55-81. Paper 2863. July.
- Forster, John W., and Raymond A. Skrinde. 1949. Control of the hydraulic jump by sills. Trans., ASCE. Paper 2415. April.
- Garton, James E., R. P. Beasley, and A. D. Barefoot. 1964. Automation of cut-back furrow irrigation. Agricultural Engineering, P. 328-329. June.

- Garton, James E. , and V.L. Hansen. 1953. A graphic solution for siphon tube irrigation problems. Miscellaneous publication No. MP-30, Department of Agricultural Engineering, Oklahoma Agricultural Experiment Station. Stillwater, Oklahoma. June.
- Gilden, Robert O. , and Guy O. Woodward. 1952. Low-cost irrigation structures. Circular 122. Agricultural Extension Services, University of Wyoming, Laramie. January.
- Hagan, Robert M. , Howard R. Haise, and Talcott W. Edminster, Editors. 1967. Irrigation of agricultural lands. No. 11 in the series, Agronomy. American Society of Agronomy. Madison, Wisconsin. 1180 p.
- Haise, H.R. , E.G. Kruse, and N.A. Dimick. 1965. Pneumatic valves for automation of irrigation systems. ARS 41-104, Agricultural Research Service, U.S. Department of Agriculture.
- Hattersley, R. T. , and B.A. Cornish. 1961. Hydraulic model investigation of 'Gabion' protection of culvert outlets. Report 48. Water Research Laboratory, University of New South Wales.
- Heede, Burchard H. 1966. Design, construction and cost of rock check dams. U.S. Forest Research Paper RM20. Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colo.
- Henderson, F.M. 1966. Open channel flow. Macmillan Series in Civil Engineering. New York. 522 p.
- Highway Research Board of the National Academy of Sciences. (No date) Culverts and storm drains, four reports. National Research Council publication 1338. Highway Research Record Number 116.
- Hinds, Julian. 1928. The hydraulic design of flume and siphon transition. Trans. , ASCE, 91:1423-1459. Paper 1690.
- Houk, Ivan E. 1951. Irrigation engineering. Vol. 1, Agricultural and hydrological phases. John Wiley and Sons, Inc. , New York. 545 p.
- Houk, Ivan E. 1956. Irrigation engineering. Vol. 2, Projects, conduits, and structures. John Wiley and Sons, Inc. , New York. 531 p.
- Howard, S. W. , and O. W. Monson. 1957. Irrigation water measurement. Bulletin 294, Extension Service, Montana State College, Bozeman. June.

- Humpherys, Allan S., and C. W. Lauritzen. 1964. Hydraulic and geometrical relationships of lay-flat irrigation tubing. Tech. Bulletin No. 1309. Agricultural Research Service, U. S. Department of Agriculture, in cooperation with Utah Agricultural Experiment Station. U. S. Government Printing Office. Washington, D. C.
- Idel'chik, I. E. 1960. Handbook of hydraulic resistance, coefficients of local resistance and of friction. Israel Program for Scientific Translation, Ltd.
- Ippen, Arthur T., and John H. Dawson, Jr. 1951. Design of channel contractions. Trans., ASCE, 116:326-346.
- Israelsen, C. Earl, and Guy O. Woodward. 1961. Prefabricated irrigation structures: design, development, and field evaluation. Engineering Experiment Station, College of Engineering, Utah State University, Logan.
- Israelsen, Orson W., and Vaughn E. Hansen. 1962. Irrigation principles and practices. Third edition. John Wiley and Sons, Inc., New York. 447 p.
- Jensen, Max C., Mel A. Hagood, and Paul K. Fanning. 1954. Irrigation structures and methods for water control. Extension Bulletin 491. Institute of Agricultural Sciences, Extension Services, State College of Washington, Pullman.
- Jeppson, Roland W. 1965. Graphical solutions to frequently encountered fluid flow problems. Utah Water Research Laboratory, Utah State University, Logan.
- Johnston, C. N. 1945. Farm irrigation structures. Circular 362. Agricultural Experiment Station, College of Agriculture, University of California, Berkeley.
- Keim, S. Russell. 1962. The Contra Costa energy dissipator. Proc., Journal of the Hydraulics Division, ASCE, 88(HY2). March.
- Kindsvater, Carl E., Rolland W. Carter, and H. S. Tracey. 1953. Computation of peak discharge at contractions. Circular No. 284, U. S. Geological Survey.

- King, Horace William. 1954. Handbook of hydraulics for the solution of hydraulic problems. 4th edition. McGraw-Hill Book Co., Inc. N. Y.
- Kirschmer, Otto. 1926. Untersuchungen über den Gefallsverlust an Rechen (Studies on head loss through a rack). Mitteilungen des Hydraulischen Institutes der technischen Hochschule München, No. 1, pp. 21-41. Munich.
- Lauritzen, C. W. 1961. Plastic films for water storage. Journal, American Water Works Association, 53(2):135-140. February.
- Lauritzen, C. W. 1963. Collapsible tubing for headgate metering device and turnout structures. Paper 63-731. Prepared for presentation at 1963 winter meeting, American Society of Agricultural Engineers, Chicago, Ill. December 10-13.
- Lauritzen, C. W. 1967. Butyl-- for the collection, storage, and conveyance of water. Bulletin No. 465, Utah Agricultural Experiment Station, Utah State University, Logan.
- Law, Shiu Wai, and Alan J. Reynolds. 1966. Dividing flow in an open channel. Proc., Journal of the Hydraulics Division, ASCE, 92(HY2), March.
- Leliavsky, S. 1965a. Irrigation engineering: canals and barrages. Chapman and Hall, Ltd. London.
- Leliavsky, S. 1965b. Irrigation engineering: siphons, weirs, and locks. Chapman and Hall, Ltd. London.
- Leliavsky, S. 1965c. River and canal hydraulics. Chapman and Hall, Ltd. London.
- Li, Wen-Hsiung, and Calvin C. Patterson. 1956. Free outlets and self-priming action of culverts. Proc., Journal of the Hydraulics Division, ASCE, 82(HY3). June.
- Lidster, William Albert. 1960. Flow characteristics and performance of broken-back transitions (outlets). Unpublished M. S. Thesis, University of Colorado, Boulder.
- Link, James R., Richard C. Tennent, and Lawrence J. Harrison. 1965. Hydraulic analysis of box culverts. U. S. Department of Commerce, Bureau of Public Roads, Washington, D. C. October.

- Loving, M. W. 1939. Concrete pipe for irrigation and drainage. Bulletin No. 18. American Concrete Pipe Association.
- McCulloch, Allan W., Jack Keller, Roger M. Sherman, and Robert C. Mueller. 1967. Ames Irrigation Handbook, 3rd edition. W.R. Ames Company.
- Moore, Walter L., Jr. 1941. Energy loss at the base of a free overfall. Trans., ASCE. Paper 2204. November.
- Morris, B. T., Jr., and D. C. Johnson. 1942. Hydraulic design of drop structures for gully control. Trans., ASCE. Paper 2198. January.
- Murdock, J. W., and C. Gregory, Jr. 1962. Elbow flow meter investigation. NBTL Project I-184. Naval Boiler and Turbine Laboratory, Philadelphia Naval Shipyard, Pennsylvania. December.
- Murley, K. A. 1969. Irrigation measuring structures. Victoria, Australia, and ratings for weir type flow. 7th Congress ICID, Mexico City, Question 24: Hydraulic structures on small channels. Report 4, pp. 24-45 & 24-62. April.
- Neill, C. R. 1962. Hydraulic tests on pipe culverts. Report 62-1. Research Council of Alberta, Alberta Highway Research, Edmonton.
- Neill, C. R. 1967. Mean-velocity criterion for scour of coarse uniform bed-material. Proceedings, XII Congress, IAHR, Vol. 3, Paper C6, p. 46-54.
- Neill, C. R. 1968. Note on initial movement of coarse uniform bed-material. Journal of Hydraulic Research, 6(2):173-176.
- Niyomthai, Chaleo. 1963. The development of a two phase flow meter. Thesis No. 40. SEATO Graduate School of Engineering, Bangkok, Thailand.
- Oazi, N. A. 1958. Stability of canal linings. Unpublished M. S. Thesis. University of Toronto, Ontario.
- Parshall, Ralph L. 1951. Model and prototype studies of sand traps. Trans., ASCE. Paper 2487. May.

- Peterka, A.J. 1964. Hydraulic design of stilling basins and energy dissipators. Water Resources Technical Publication, Engineering Monograph No. 25. U.S. Department of the Interior, Bureau of Reclamation. U.S. Government Printing Office, Washington, D.C. 222 p.
- Pillsbury, Arthur F. 1952. Concrete pipe for irrigation. Circular 418, California Agricultural Experiment Station, University of California. November.
- Portland Cement Association. 1946. Concrete soil-saving structures-- check dams and flumes. Chicago, Ill.
- Portland Cement Association. 1957. Lining irrigation canals. Chicago, Ill.
- Portland Cement Association. 1960a. Concrete pipe irrigation systems. Chicago, Ill.
- Portland Cement Association. 1960b. Concrete structures for irrigation uses. Chicago, Ill.
- Portland Cement Association. 1962. Culvert design aids: An application of U.S. Bureau of Public Roads culvert capacity charts. Chicago, Ill.
- Portland Cement Association. 1964. Handbook of concrete culvert pipe hydraulics. Chicago, Ill., 267 p.
- Pugh, W.J., and N.A. Evans. 1964. Weed seed and trash screens for irrigation water. Popular Bulletin 522-5, Agricultural Experiment Station, Colorado State University, Fort Collins, Colorado. November.
- Rasheed, Hameed. 1963. Utah State University stilling basin pipe flow to open channels. Unpublished M.S. Thesis. Utah State University, Logan. 47 p.
- Ree, W.O. and W.R. Gwinn. 1958. Tests of a closed conduit spillway debris guard and anti-vortex baffle. Research Report No. 313. Watershed Technology Research Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture. October 29.
- Replogle, J.A. 1969. Flow measurement with critical depth flumes. 7th Congress ICID, Mexico City. Question 24: Hydraulic structures on small channels. Report 15, pp. 24-215-24-235. April.

- Replogle, John A., Lloyd E. Meyers, and Kenneth J. Burst. 1966. Evaluation of pipe elbows as flow meters. Proc., Journal of Irrigation and Drainage Division, ASCE, 92(IR3):17-34. September.
- Rhone, Thomas J. 1959. Problems concerning use of low head radial gates. Proc., Journal of the Hydraulics Division, ASCE, 85(HY2): 35-65. February.
- Rippon, Frank E. 1962. General design considerations for canals and canal structures. Irrigation Operators's Workshop. U.S. Bureau of Reclamation, Denver Federal Center, Denver, Colorado.
- Robinson, A.R. 1962. Vortex tube sand trap. Trans., ASCE. Vol. 127, Part III. Paper 3371.
- Robinson, A.R. 1964. Water measurement in small irrigation channels using trapezoidal flumes. Paper 64-210. Presented at 1964 annual meeting, American Society of Agricultural Engineers, Fort Collins, Colorado. June.
- Robinson, A.R., C.W. Lauritzen, and D.C. Muckel. 1963. Distribution, control and measurement of irrigation water on the farm. Miscellaneous Pub. No. 926, U.S. Department of Agriculture. U.S. Government Printing Office, Washington, D.C. July.
- Rouse, Hunter, B.U. Bhoota, and En-Yun Hsu. 1951. Design of channel expansion. Trans., ASCE, 116:347-363.
- Schwab, Glenn O., Richard K. Frevert, Talcott W. Edminster, and Kenneth K. Barnes. 1966. Soil and water conservation engineering. 2nd edition. John Wiley and Sons, Inc., New York. 683 p.
- Searcy, James K. 1965. Design of roadside drainage channels. Hydraulic Design Series No. 4. Hydraulic Branch, Bridge Division, Bureau of Public Roads, U.S. Government Printing Office, Washington, D.C.
- Shen, H.W., V.R. Schneider, and S.S. Karaki. 1966. Mechanics of local scour. CER66HWS22. Civil Engineering Department, Engineering Research Center, Colorado State University, Fort Collins.
- Simmons, W.P., Jr. 1964. Hydraulic design of transitions for small canals. A Water Resources Technical Publication, Engineering Monograph No. 33. U.S. Department of Interior, Bureau of Reclamation.

- U. S. Soil Conservation Service. 1962. Irrigation Handbook, Section 15, Chapter 9 (lithographed). Washington, D. C.
- U. S. Soil Conservation Service. 1954. Irrigation water desilting box and trash screen. Portland, Oregon. January.
- Utah State Department of Highways. 1965. Manual of instruction. Part 4, Roadway drainage. Salt Lake City, Utah.
- Vallentine, H. R., and B. A. Cornish. 1962. Notes on the design of culverts with outlet scour control. Water Research Laboratory, University of New South Wales. March.
- Vanoni, Vito A., and Robert E. Pollak. 1959. Experimental design of low rectangular drops for alluvial flood channels. Report No. E-82. Sedimentation Laboratory, California Institute of Technology, Pasadena. September.
- Wei, Chi-Yuan. 1968. Design criteria for USU stilling basin pipe flow to open channels. Unpublished M.S. Thesis, Utah State University, Logan.
- Willson, George B. 1963. A self-regulating headgate for control of ditch-water flow. Paper prepared for presentation at winter meeting of American Society of Agricultural Engineers, Chicago, Ill., December 10-13.
- Woodward, Guy O. 1959. Sprinkler irrigation. 2nd edition. Sprinkler Irrigation Association, Washington, D. C. 378 p.
- Yaremko, Eugene Kenneth. 1966. Energy dissipation by cascades. Unpublished M.S. Thesis. University of Alberta, Edmonton. April.
- Zimmerman, Josef D. 1966. Irrigation. John Wiley and Sons, Inc., New York. 516 p.