HYDRAULICS

RESEARCH, LABORATORY AND FIELD STUDIES

FISCAL YEAR 1966
SUMMARY REPORT

HYDRAULICS BRANCH BUREAU OF RECLAMATION DENVER, COLORADO

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HYDRAULICS BRANCH
DIVISION OF RESEARCH
OFFICE OF CHIEF ENGINEER
Denver, Colorado
July 1966

SECTION I--INTRODUCTION

The Hydraulics Branch in 1966 experienced a greater work program of laboratory studies for outside agencies and foreign governments, a greater number of field studies, and fewer laboratory studies for project design. Greater effort was made in the direction of research, especially in the field of techniques and instrumentation.

The mid-1960's are witnessing a tremendous upsurge in hydraulic research throughout the world. Techniques heretofore seldom used are being exploited to meet unprecedented requirements. Particularly notable are mathematical studies, utilization of a wide variety of highly sensitive instruments, and computer techniques.

During the year a sizeable number of the staff took on the responsibilities of continuing education in several technical specialities such as mathematics, instrumentation, and various types of writing. A summary of these courses is presented in Section VI.

It is recognized that modern research equipment and instrumentation are essential for successful pursuit of the more complex hydraulic research in the future. To take full advantage of up-to-date modeling practices, modern measuring devices, automatic data acquisition, data processing, and eventual computer-directed model operation, extensive equipment additions and rehabilitations are being acquired. The existing facilities in the north half of the laboratory for controlling and measuring flows of water to models are being modified, updated, and improved. New hydraulically operated, wedge-type gate valves, pilot valves, valve position indicators, manometers, graphic control panels, automatic rate-of-flow measurements, rate-of-flow readout pressure gages, and control equipment with remote operating capabilities were purchased.

Also, the Branch acquired the following hardware to improve the quality and variety of data acquisition capability: pressure transducers, quartz thermometer with two-probe and digital or analog readout; a 12-inch pump to replace an old and inadequate pump, a 12-inch and three 3-inch Venturi meters. Other important acquisitions included a precision integrating digital voltmeter; pressure transducer calibration equipment; and a frequency analyzer system to be used with present electronic instrumentation to detect undesirable periodic fluctuations in laboratory or field hydraulic tests.

W. E. Wagner and W. P. Simmons represented the Bureau of Reclamation at the XI Congress, International Association for Hydraulic Research, held in Leningrad, September 6-11, 1965. The congress was attended by approximately 450 delegates representing 39 countries. Over 150 papers were presented at the technical sessions covering the subjects of high-velocity flow, outfall of waste water, unsteady flow in open channels, and hydroelasticity. Two papers from the Bureau were presented: "Applied Research in Cavitation in Hydraulic Structures," and "Surges in a Trapezoidal Canal Due to Pump Flow Rejection." Concurrently with the technical sessions, seminars were held in which low temperature effects on flow in rivers and reservoirs, seepage of water in nonsaturated porous media, hydrodynamic forces in hydraulic machinery, and sediment transport and diffusion problems in coastal hydraulics were discussed. Following the congress, the representatives participated in study tours to Moscow, Eastern Siberia, and Southern Ukraine. A total of 10 research institutes, several industrial plants, and 7 hydrostations were visited on the tours or while in Leningrad. In addition to the facilities in the Soviet Union, hydraulic laboratories in Switzerland, France, Italy, England, and Sweden were visited. Participation in the XI Congress and visits to European hydraulic laboratories and institutes afforded an opportunity to discuss methods of approach to problems in mutual interest, to learn types of work being conducted by our European counterparts and to evaluate the quality of the work and people in other countries.

During the week of November 15-19, 1965, Peterka conducted classes in Water Measurement Procedures and presented slide-illustrated lectures to the four groups of irrigation operators attending the workshop. In all, over 120 participants were given the course in Water Measurement. In addition, seminars were held during the scheduled class time and problems in water measurement were discussed. As part of the instruction, Schuster conducted a laboratory course in Water Measurement in which various types of water measurement devices were explained and demonstrated.

During the week of December 1-3, 1965, Peterka traveled to Utah State University at Logan, Utah, to conduct classes in Water Measurement Procedures at the First Annual Irrigation Operators Work Shop sessions held in the University facilities. The work shop was sponsored by Utah State University and the Utah Water Users Association in cooperation with the Utah Water and Power Board, Bureau of Reclamation, Soil Conservation Service, and State Engineer of Utah. The water measurement course consisted of three 4-hour lectures which included some laboratory demonstration work. In all, there were about 150 participants in this work shop.

December 6-8, 1965, Peterka participated in the 7th Annual Contractors Meeting, Isotope Systems Development Program, U.S. Atomic Energy Commission, Washington, D.C. The purpose of the meeting was to review the progress of the 38 projects being worked on by various organizations under the jurisdiction and support of the AEC. Peterka reported on the progress of our investigations in our two projects, "Development of Accurate Flow Measuring Procedures for High Head Turbines," and "A Radioisotope Study of Reservoir Leakage at Anchor Dam Reservoir."

On December 31, 1965, Peterka traveled to Phoenix, Arizona, and participated in aerial survey of flood conditions on the Verde and Salt Rivers upstream from Phoenix, Arizona. The combined releases from these river systems resulted in a discharge of 75,000 cfs through the city of Phoenix, which destroyed bridges and caused some property damage. The purpose of the aerial survey was to inspect the dams and their spillways to determine that they were operating properly and that no obviously dangerous conditions existed. The study continued through January 1, 1966, when a meeting was held with the local personnel, at which time they were assured that the structures were capable of even greater flood releases without fear of structural damage or failure of the dams.

W. P. Simmons attended and presented a technical paper at the third annual seminar sponsored by the Southern Idaho Section, ASCE, in Boise, Idaho. The seminar, "Hydraulics and Water Resources," was held on November 18-19, 1965, and was attended by about 110 engineers from the area. Talks were presented on fundamental equations in hydraulics, flow in open channels, and flow in closed conduits. The latter paper was presented by Mr. Simmons and emphasized specific problems found to be troublesome with high-head or high-velocity flows.

A. J. Peterka participated in Value Engineering Team No. 1, which explored critically the Bureau engineering of hydraulic intakes to penstocks including all features including bellmouth entrances, gates, slots, submergence, and trashracks. The team has disclosed the desirability of extensive research including a hydraulic model study.

Henry Falvey assisted in the critical review of 15 conceptual designs for a 50-mgd desalination plant for the Office of Saline Water.

Research Hydraulic Engineer P. "F." Enger performed special Research Division staff assignments in the general field of computer technology, data acquisition equipment studies, and instrumentation requirements of the Division; details are noted in Section VIII.

Harold M. Martin served on the Program Committee representing the Hydraulics Division for the Fourth Conference on Water Resources, American Society of Civil Engineers, held in Denver, Colorado, May 16-20, 1966. He presided at two sessions sponsored by the Hydraulics Division.

Messrs. Martin, Wagner, and Carlson again assisted in the College Contact Program of the Bureau by lecturing to engineering classes, seminars, and professional society student chapter meetings. Martin spoke at the University of Tennessee and the Agricultural and Technical College of North Carolina; Wagner at University of Iowa and Purdue; and Carlson at Iowa State.

Martin was appointed Chairman, Water Resources Coordinating Committee, American Society of Civil Engineers, for a term ending October 1968. The committee has the responsibility for surveillance and coordination of the water resources activities of five major technical divisions of the Society.

A major effort was made by the Branch to complete the revision of the Water Measurement Manual. W. P. Simmons spent over 5 months full time in preparing the text. A. J. Peterka reviewed the manuscript, making corrections, and suggestions.

The staff was requested to evaluate a number of research proposals for the Office of Water Resources Research.

Danny L. King and P. "F." Enger presented papers to the ASCE Water Resources Conference, as noted in Section VI.

James E. Fay, Hydraulic Engineering Technician, retired December 31, 1965, after more than 30 years' service with the Bureau of Reclamation.

J. P. Ambrusch, Exhibits Specialist, retired December 31, 1965, after 25 years' service. He received the Silver Medal for Meritorious Service.

Quality Increases in salary were awarded W. E. Wagner and Laura Hawthorn for superior performance. Danny L. King earned a cash award for superior work in research.

SECTION II--STUDIES FOR BUREAU PROJECTS

The Hydraulics Branch studied a number of interesting problems of hydraulic design of structures and problems of the behavior of structures and equipment. Several required the use of hydraulic models and others were solved by drawing on data available in laboratory reports, papers, and other file material.

Hydraulics Branch reports, papers, and publications issued this year are listed in Section VII of this report. Over 500 pages of notes were dictated during the year, describing the activities of the branch, including consultations, technical correspondence, technical conferences, and related responsibilities.

The major studies of the year were:

- Tehama-Colusa Spawning Channel
- Yellowtail Dam outlet works
- Navajo Dam outlet works
- Crystal Dam spillway--1:24 sectional model
- Crystal Dam spillway--1:40 model
- El Vado Dam outlet works
- Folsom Dam stilling basin
- Folsom Dam outlet conduits
- Trinity Reservoir turbidity
- Glen Canyon Dam
- Silver Jack Dam outlet
- Capacity test--Salt Lake Aqueduct, Provo River Project

Tehama-Colusa Canal Spawning Channel

Research on the hydraulics of salmon spawning beds continued this year. It was previously demonstrated that the use of an underdrain system was not effective, and that water and air jets directed into the gravel are not sufficient to clean sediment out of spawning gravel 2-1/2 feet in depth. The use of a floating barge as a partial dam across the channel to increase water velocity over and through the gravel, as in a natural channel flood, was next investigated in various forms. The barge, 30 feet wide in the direction of channel flow, was placed 0.2 times the expected upstream water depth above the gravel bed. This resulted in cleaning the gravel to a depth of greater than 1 foot in the model. Efforts were then made to increase the efficiency of cleaning. A baffle placed at the upstream end of the barge, placed at 0.4 times the upstream water depth above the gravel, resulted in a faster cleaning rate, but it restricted the cleaning action to the vicinity of the baffle. Baffles extended from the upstream and downstream ends of the barge resulted in cleaning two local areas close to the baffles. An additional baffle, extending down from the midpoint of the barge, resulted in cleaning for the full length of the barge, but a longer time was required to clean to a 1-foot depth in the model.

It was next shown by tests made in the 1-foot-wide by 2-foot-deep by 7-foot-long flume that a single baffle or several baffles operating simultaneously are effective in removing fine sediment from the 3/4- to 4-inch spawning gravel. The baffles are, in effect, vertical planes with the bottom edges placed just above the gravel. Both fine sand (200 microns) and silica flour (5 to 40 microns) have been used in the tests and represent the fine sediment expected to deposit in the prototype spawning gravel. The baffles are effective because of the head drop across the baffle, which causes an increase in flow velocity beneath the baffle. If the baffle produces too much resistance to flow, water passes over the top of the baffle or through holes in the baffle.

A 1:1 scale sectional model was used to develop a movable baffle placed transversely to the flowing water in the canal which causes the gravel to be moved under the baffle forming a transverse channel in the gravel, Figure 1. The baffle is moved upstream against the flowing water and a differential head created across the baffle causes the flowing water under the baffle to peel off layers of spawning gravel, move it under the baffle, and deposit it on the downstream slope of the transverse channel.

As the gravel is moved, deposited sediment in the gravel voids is washed up into the flowing water above the gravel where it is carried downstream in suspension. Denver staff and field personnel and representatives from the Fish and Wildlife Service have observed cleaning tests, and it is the consensus that this method be used in Tehama-Colusa Canal.

In connection with this research and development program, a hydraulic engineer from the Hydraulics Branch and a mechanical engineer from the Mechanical Branch inspected Priest Rapids artificial spawning channel at Priest Rapids Dam on the Columbia River and the Abernathy Salmon Cultural Laboratory and Incubation Channel on Abernathy Creek, both in the State of Washington. They discussed gravel cleaning techniques and requirements for cleaning spawning channels in general, and for cleaning Tehama-Colusa proposed spawning channel in particular. Thirty-seven biologists and engineers took part in discussions at Priest Rapids Dam and 17 biologists and engineers took part in duscussions at the Bureau of Commercial Fisheries Office at Portland, Oregon. Descriptions and a motion picture of gravel-cleaning operations tested in the Denver Hydraulics Laboratory were given by the laboratory engineer at both meetings.

Yellowtail Dam Outlet Works--Pressure Distribution and Acceleration Measurements

Representatives of the Hydraulics and Dams Branches planned for and instrumented test equipment in the center wall of the outlet works

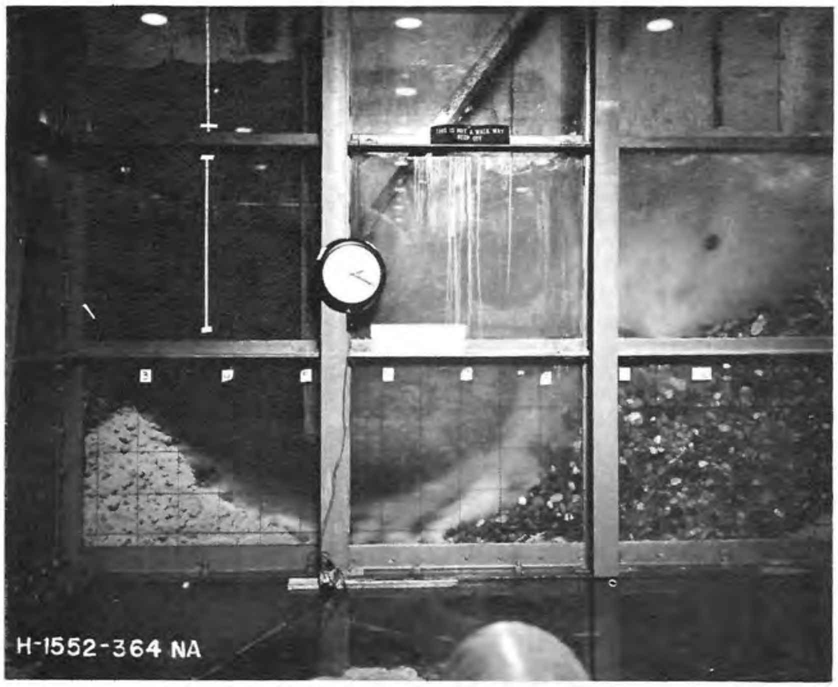


Figure 1. A full-scale sectional model was used to develop a technique of removing sediment from the spawning gravel in the Tehama-Colusa Canal. Fine sediment is washed from the gravel as a baffle gate is moved slowly upstream.

stilling basin, for making pressure and accelerometer measurements. Measurements were made in November 1965, for flows of 150 and 500 cfs through one side of the basin containing an 84-inch hollow-jet valve evacuation outlet, Figure 2. The unbalanced pressure force, caused by the 500-cfs flow, was less than 0.5 psi, and no wall movement was indicated by the accelerometers.

Pressure transducer and accelerometer measurements in the outlet works stilling basin were again performed in December and January. The December series of measurements covered a discharge range of 1,000 to 2,000 cfs, and the January measurements covered a range of 2,250 to 3,100 cfs. The approximate maximum change in pressure on the center wall was 30 feet of water for the 3,100-cfs discharge. No movement of the center wall was apparent from a recording of the output of the accelerometer.

Before the start of this test series, 12 pieces of rock, forming a part of the riprap slope downstream of the basin, were numbered and their position was recorded. These rocks have been observed during the test series, and prior to the January tests, it was noted that a few had been disturbed by waterflow.

Navajo Dam Outlet Works Stilling Basin

A 1:12 scale model was tested to determine the causes of and remedies for recent damage to the stilling basin for the 72-inch hollow-jet valve outlet works, Figure 3. Severe abrasion damage was observed at several locations in the basin, and the center dividing wall exhibited compression failure of the concrete near its base. The model demonstrated the rapid circulation of large gravel within the basin. The area of circulation is dependent upon the discharge, head, and tailwater elevation. For example, at 100 percent valve opening, under conditions of head and tailwater observed during prototype operation, gravel circulated near the downstream end of the model stilling basin. For 30 percent valve opening, violent circulation occurred in the upstream end of the basin, adjacent to the downstream end of the contracting wedges. Material with a maximum size of about 3 inches (36-inch prototype) was used in the tests. Smaller material, up to about one-half inch in size, was lifted from the basin floor, and at times was thrown out of the water. Differential heads equivalent to about 20 feet of water were recorded on the center wall for 100 percent valve opening. The higher head changed from one side of the wall to the other at a frequency of about 7 or 8 cycles per second. The differentials acting on the wall decreased, in general, with a decrease in discharge. The vibration of the wall was recorded simultaneously with the differential pressure to obtain a qualitative estimate of the vibration characteristics of the model wall.

A. Transducer mounted in sealed container.

B. Installation of transducers in outlet stilling basin wall.

Figure 2. Yellowtail Dam outlet works dynamic pressure measurements. --

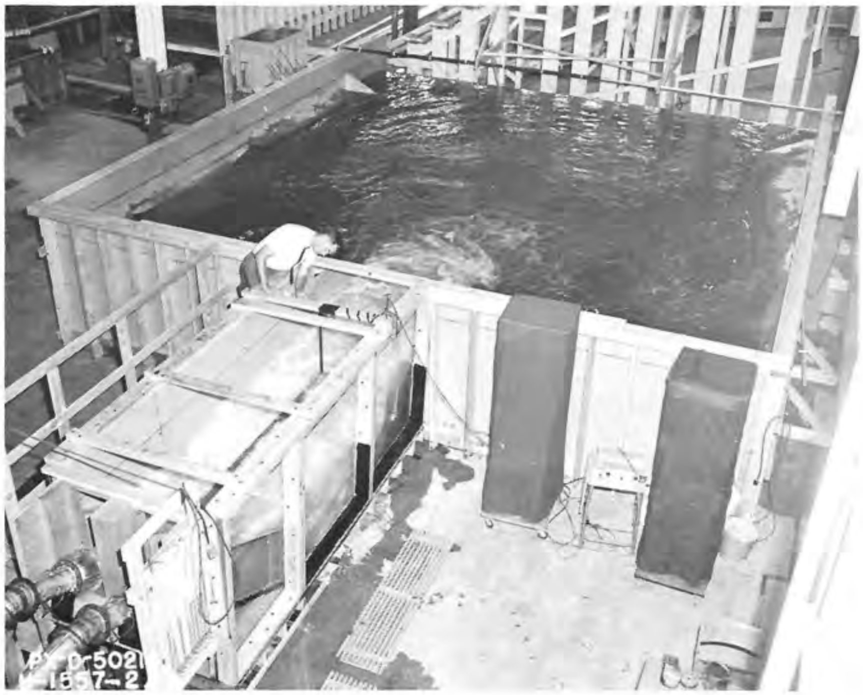


Figure 3. 1:12 model of stilling basin, Navajo Dam outlet works. Dynamic pressure measurements were made on critical parts of the structure.

Modifications included removal of the converging wedges and original center wall, testing of several configurations of the center wall, installation of sloping chutes to increase the degree of impingement of the hollow jets, and improvement of the downstream river channel. Tests made on these modifications consisted of visual observation of flow conditions in the basin and river channel, observation of the circulation of abrasive material in the basin and the tendency for material to be pulled into the basin from the downstream channel, recording of instantaneous pressures and vibration on the center wall and outside walls, scour in the downstream channel, and abrasion of the basin flow surfaces by circulating material.

The most acceptable modification appears to include complete removal of the converging wedges and center wall, installation of a 2-1/2:1 sloping chute at the upstream end of the basin, and the addition of 12 inches additional concrete to the inner surfaces of the outside walls and the basin floor. Also, the bottom end slopes of the downstream channel will be paved with an 18-inch thickness of concrete for a distance of approximately 140 feet downstream from the end of the basin. The downstream channel improvement will also include walls and fences at the tops of the paved slopes to prevent material from entering the channel and a trap at the downstream end of the stilling basin to collect material which might enter the paved area by some presently unknown means. The model simulation of the improved downstream area is shown in Figure 4.

The allowable outlet works discharge will be reduced to 3,200 cfs at the maximum reservoir elevation 6101.5 (compared to a maximum discharge capacity of about 4,720 cfs). Operation at discharges above this amount would result in strong surging in the basin and high waves in the downstream channel. Also, balanced operation (both valves discharging equally) is necessary for satisfactory stilling basin flow conditions because of the absence of a center dividing wall. Operation of the final modification is shown in Figure 5.

Crystal Dam Spillway

A 1:24 scale sectional model of the left bay of the spillway was studied to determine approach flow conditions, discharge capacity, and pressure distribution on the crest profile for gate-controlled and uncontrolled flows.

Uncontrolled flow around the left approach wall, through the gate section and on the spillway crest was very smooth at all discharges. The water surface drawdown at the approach wall was negligible and flow past the center pier was smooth. There was some indication that a fin of water would form at the end of the pier, where flows from the two bays would meet. However, this could not be definitely determined on this model, but was carefully studied on the comprehensive 1:40 scale model of the

Figure 4. Model simulation of paved downstream channel, Navajo Dam outlet works.

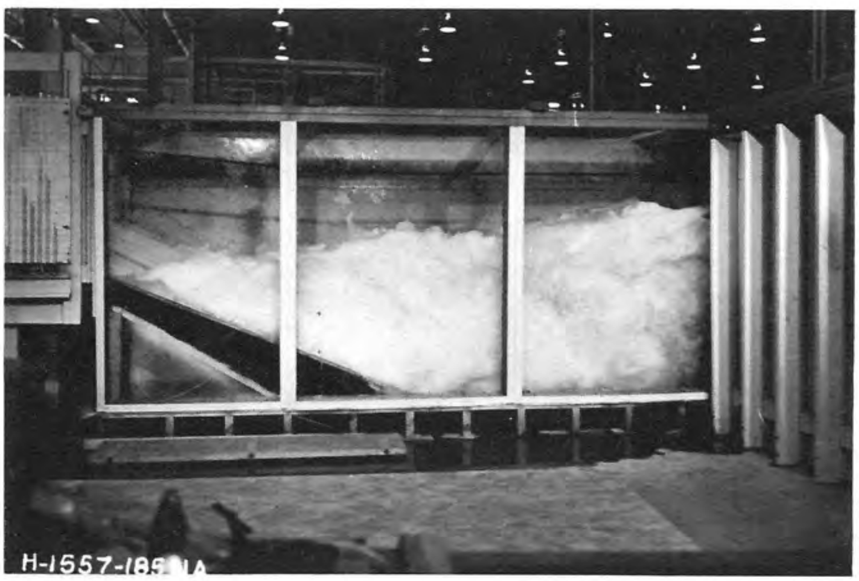


Figure 5. Flow conditions in final modification of stilling basin. Q = 3,200 cfs.

entire structure. Gate-controlled flows were generally satisfactory, but at gate openings of less than 6 feet with near maximum reservoir elevations, the flow separated from the left side and climbed the center pier. This flow condition, while unsightly, would not fill the tunnel; however, modifications will be determined to correct this.

Pressures on the crest profile were near or above atmospheric for all gate openings and reservoir elevations. The lowest pressure recorded was equivalent to 1.3 feet of water below atmospheric. Discharge measurements indicated that at maximum reservoir elevation 6750.0, the spillway would pass 42,750 cfs, within 1 percent of the design maximum discharge of 42,400 cfs.

Hydraulic studies in a 1:40 scale model were initiated to investigate the hydraulic characteristics of the Crystal Dam spillway. The model includes upstream topography, the spillway intake, the spillway tunnel, a spillway stilling basin, outlet works stilling basin, powerplant, and approximately 1,600 feet of downstream topography. The first phase of the study will be concerned with the design of the spillway stilling basin so that the basin will function as an energy dissipator for low flows and as a flip bucket for high discharges. The second phase will investigate flow conditions throughout the entire system, as well as the erosion patterns downstream from the spillway stilling basin. The testing of the first phase is essentially complete. It was found that sweepout (that is the transition from an energy dissipator to a flip bucket) occurred within 5 percent of the discharge required in the original design. The necessary model construction required for the second phase has been initiated.

The sweepout discharge for the spillway stilling basin was only 500 cfs greater than the 11,200 cfs predicted by the Design Division. With the jump in the basin, no problems were experienced by flows which tended to touch the roof of the basin. The barrier formed by the erodible bed material during discharges in excess of 11,700 cfs increased the tail-water depth in the vicinity of the outlet works stilling basin by 1 to 2 feet.

Crystal Dam Outlet Works

A 1:12 scale hydraulic model was constructed of the outlet works for Crystal Dam, Curecanti Unit, Colorado River Storage Project, Colorado. The model includes the two slide gates, the hydraulic jump stilling basin, and a portion of the downstream channel. The slide gates are 3 feet 3 inches square and control discharges up to a maximum of 1,900 cfs. The maximum head on the gates is approximately 212 feet. The energy dissipating efficiency and hydraulic-operating characteristics of the stilling basin will be determined. Special attention is being given to the hydrodynamic forces acting on the center wall and to the possible tendency for sand and gravel to be pulled upstream into the stilling basin from the downstream channel. Instrumentation being planned for the prototype structure will allow valuable comparisons to be made between the model and prototype.

Several design schemes have been tested for the development of a curtain wall to protect the slide gates from surging action during high tailwater conditions. Tentatively, the recommended curtain wall has been located near the upstream end of the basin, about 15 feet downstream from the gates.

El Vado Outlet Works--San Juan-Chama Project

A flip bucket was developed from model studies that minimized river channel erosion and provided satisfactory dispersion of flows for the enlarged capacity outlet works (Figure 6). The bucket was composed of a left and right vertical wall and two sloping plane surfaces. An offset opening in the right wall provided for passage of small flows. The bucket was designed so that optimum dispersion resulted for normal discharges (2,000 to 4,000 cubic feet per second). Somewhat less desirable conditions occurred for discharges from 4,500 cubic feet per second up to the maximum of approximately 7,000 cubic feet per second. A hydraulic jump occurred upstream of the flip bucket and in the outlet works tunnel for releases of less than 2,000 cubic feet per second. Model erosion studies indicated that the horizontal apron downstream of the flip bucket should be lowered from elevation 6720 to elevation 6715 and the apron support modified to contain a mass concrete wedge-shaped key. These modifications were necessary to minimize chances of erosion undercutting the apron. Riverbed erosion from operation of the existing spillway was much more extensive than for similar releases through the outlet works. However, with the greatly increased capacity of the outlet works, spillway operation is not anticipated. Photographic coverage of the model, including movies, was obtained in two locations which can be duplicated at the prototype installations for future model prototype comparisons.

Folsom Dam Stilling Basin

A laboratory engineer and a Dam's Branch engineer inspected the Folsom Dam stilling basin to determine the extent of concrete damage caused by rocks circulating in the basin. The stilling basin is a combined sloping apron-horizontal apron hydraulic jump-type, approximately 325 feet long by 400 feet wide by 68 feet deep with a 15-foot-high sill at the downstream end. Downstream from the basin, a flow channel was excavated in rock on a 4:1 upward slope to the American River. The rock in this area was badly fractured by explosives and large angular pieces, up to 6 or 8 feet on a side, remained in the flow channel. Since 1955, there have been frequent small discharges and four major flood discharges through

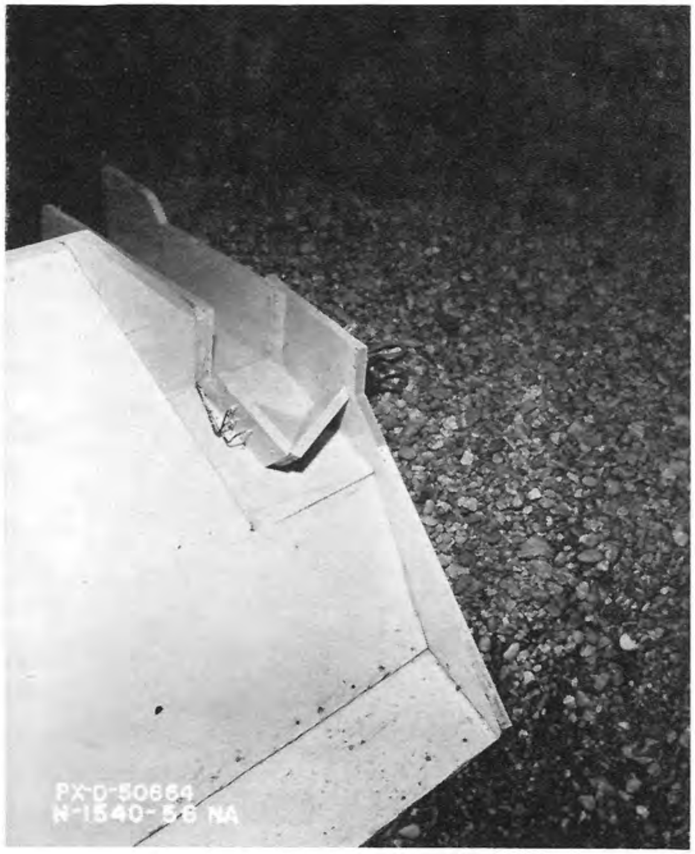


Figure 6. Downstream view of El Vado Dam outlet works flip bucket.

the basin. The largest discharge occurred in 1965 and was about 115,000 cubic feet per second. The basin was initially unwatered and inspected in 1956 following a large discharge and some abrasive damage to the concrete, estimated to be about 0.1 foot deep was noted. At that time, it was estimated that there was about 300 cubic yards of sand, gravel, and rock in the basin, but it was recommended that the material not be removed. Following the 1965 flood discharge, an underwater inspection indicated large deposits of rock and gravel, exposed reinforcing bars, and extensive damage to the concrete. The basin was unwatered so that the debris could be removed and the extent of damage determined. The horizontal portion of the basin contained large piles of rock and gravel estimated to contain about 400 cubic yards. The material ranged in size from about sand particles up to about 2 cubic yards. Reinforcing bars in the vertical end sill had been torn loose; some were still fastened at one end, others were completely free and were interspersed with the rock. Lengths of pipe, wire, rivets, and other material were also mixed in with the rock. The sloping and horizontal portions of the apron, the end sill, and the sidewalls up to a height of about 25 feet were severely abraded. A section of the floor reinforcing steel in the left side of the sloping apron was exposed but had not been torn loose. It was estimated that about 6 or 8 inches of concrete had been abraded from the apron. There was also evidence of cavitation damage at a joint in the curve at the upstream end of the basin. These cavitated areas were not extensive in surface area, but were as much as 18 inches deep. It was recommended that all of the debris and rock be removed from the basin. Repairs to the apron cannot be made this year since it is necessary to discharge through the basin to provide a flood control pool in the reservoir. However, a pump intake line is being provided through the right basin wall into the powerhouse, so that the project forces can unwater the basin in the future.

Folsom Dam Outlet Conduits

Simultaneous operation of the spillway and outlet works of Folsom Dam during heavy runoffs this spring produced extensive erosion damage where the outlet conduits join the spillway face. This damage is unique and unexpected because none had been encountered with outlet flows alone, and only relatively minor damage had occurred with large spillway flows. To determine the cause of the difficulty, and to develop a practicable solution, hydraulic model studies have been initiated. A 1:16.7 scale model of a short section of the spillway and one outlet conduit was constructed in the laboratory (Figure 7). Water supplied separately to the spillway and to the outlet conduit so that any appropriate combination of spillway and/or outlet flow and velocities can be represented.

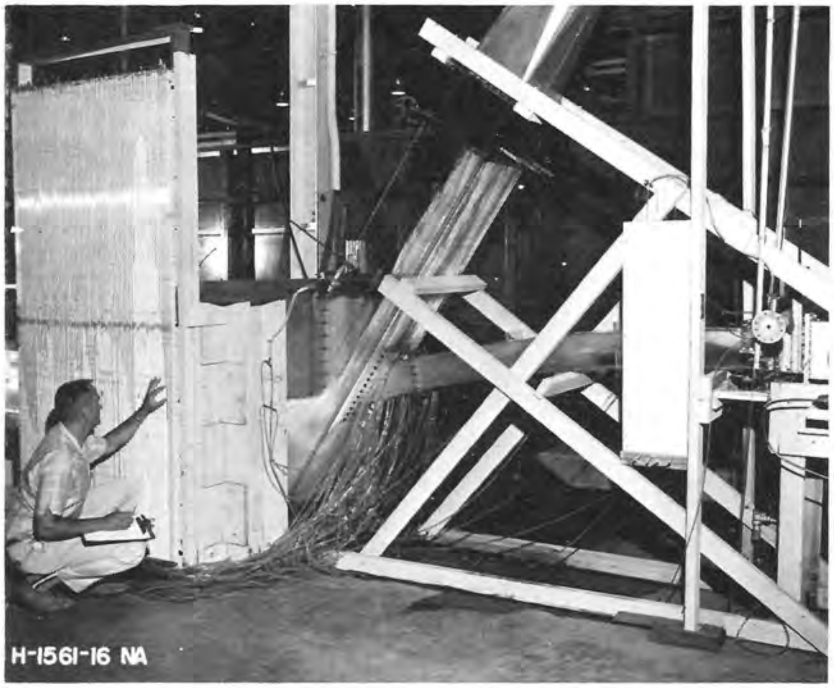


Figure 7. Hydraulic model (1:16.7 scale) of a single upper tier outlet and junction with spillway, Folsom Dam. Studies are aimed at alleviation of negative pressures at the juncture.

Tests on the 1:16.7 model of a single upper tier outlet and junction with the spillway face have indicated that an inadequate supply of air in critical areas was the principal cause of damage to the structure. Trial releases have been made in the model to determine the best method of passing large flows for the present flood season. These tests show that the outlet gates should be opened 60 percent to obtain optimum pressure conditions when simultaneous spillway releases are necessary to pass flood flows. Further studies will be made utilizing an "eyebrow" placed on the spillway face above the outlet works blockouts to prevent spillway flow from impinging on the outlet works invert. Also, a flow spreader protruding through the spillway jet above the outlet works portals will be tested as a means of providing adequate aeration.

Problem of Turbid Releases from Trinity Reservoir

The Chemical Engineering Branch and Hydraulics Branch are cooperating with the Hydrology Branch in an attempt to evaluate the cause of the turbid releases. Limited tests on water samples provided by field personnel indicate that withdrawals are being made from a stratification layer on the bottom of Clair Engle Lake which contains very small particles of clay materials which remain in suspension. The source of these materials has not yet been determined. The chemical quality of the water is good, indicating that the problem is primarily one of aesthetics.

Glen Canyon Dam

In company with Messrs. Arthur, Sheda, A. T. Lewis, R. T. Larsen, and Lindholm, Peterka inspected the left tunnel spillway and the tunnel-plug outlet works. Particular attention was given to the flow surfaces in the tunnel which had not yet operated. Recommendation regarding flow surface irregularities were made and the need for more stringent specifications and inspections was pointed out. The damage in the tunnel-plug outlet works flow passages, resulting from extensive operational discharges, was observed; and offsets and other irregularities, that produced the cavitation damaged areas, were noted.

Hydraulic Model Study of the Silver Jack Dam Outlet Works Bypass for Bostwick Park Project, Colorado

A model study was made to determine the operating conditions of a jet-flow gate and downstream pipe when discharging a maximum of 36 cfs into the main outlet works stilling basin. A 1:2.857 scale model of the 10-inch-diameter jet-flow gate, the downstream pipe, and the right half of the outlet works stilling basin was tested to determine the proper alinement of the gate and pipe to minimize waves and splashing in the stilling basin. The tests showed that the jet-flow gate and downstream pipe should be placed at a lateral angle of 9 degrees toward the centerline of the basin and tipped downward 30 degrees below horizontal. Air demand immediately downstream of the jet-flow gate was investigated. Most of the air demand was satisfied by air flow upstream through the discharge pipe and a small percent of the air flow was through the air vent pipe.

Capacity Test of the Salt Lake Aqueduct--Provo River Project, Utah

The Regional Director, Salt Lake City, Utah, requested a test of the Salt Lake Aqueduct to determine the maximum capacity in connection with planning for delivery of Central Utah Project water to Salt Lake County, Utah. The 32.2-mile-long upstream portion of the 41.7-mile-long aqueduct is involved in plans for additional water delivery. Equipment necessary to evaluate capacity of the aqueduct was installed, including dye injection and withdrawal facilities for color-velocity and color-integrated sample discharge measurements; and data were obtained during an initial test with the design discharge of 150 cfs. Satisfactory test data were obtained along the upstream 32.2-mile portion of the aqueduct. During this test, serious erosion of earth materials occurred adjacent to a steep wasteway chute that was used to divert the aqueduct flow into a creek. This necessitated postponement of additional tests, needed to determine the maximum capacity of the aqueduct, until corrective work is completed at the wasteway. The data obtained with the design discharge indicate that the aqueduct will safely convey more than 150 cfs. The extent of additional capacity will be determined about midsummer 1966 when conditions will be most favorable for diversion of water at the downstream end of the aqueduct test reach.

SECTION III--COOPERATION WITH OUTSIDE AGENCIES

Cooperative and assistance were rendered other agencies on several hydraulic problems. Most extensive were studies for the Oroville Dam project of the Department of Water Resources, State of California, and investigations for the Office of Saline Water.

Oroville Dam Flood Control Outlet

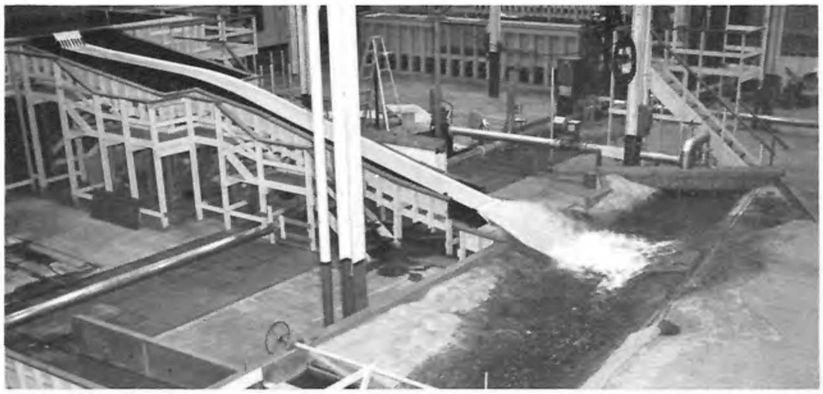
The 1:78 scale model studies were completed and a comprehensive report entitled "Hydraulic Model Studies of the Flood Control Outlet and Spillway for Oroville Dam," California Department of Water Resources, State of California (Report No. Hyd-510) was published.

For the final phase of the model investigations, the model was modified to reflect the configuration shown in the construction specifications (Figure 8A). Particular emphasis was placed, during these tests, on developing dispersion blocks for the end of the spillway chute that would be free of adverse pressure conditions noted in the preliminary studies. For the recommended blocks, the upstream outside corner was reshaped to allow aeration of an area where pressure in the cavitation range had previously been noted and the chamfer on the top inside edge of the block was modified to alleviate subatmospheric pressures in that area (Figure 8B).

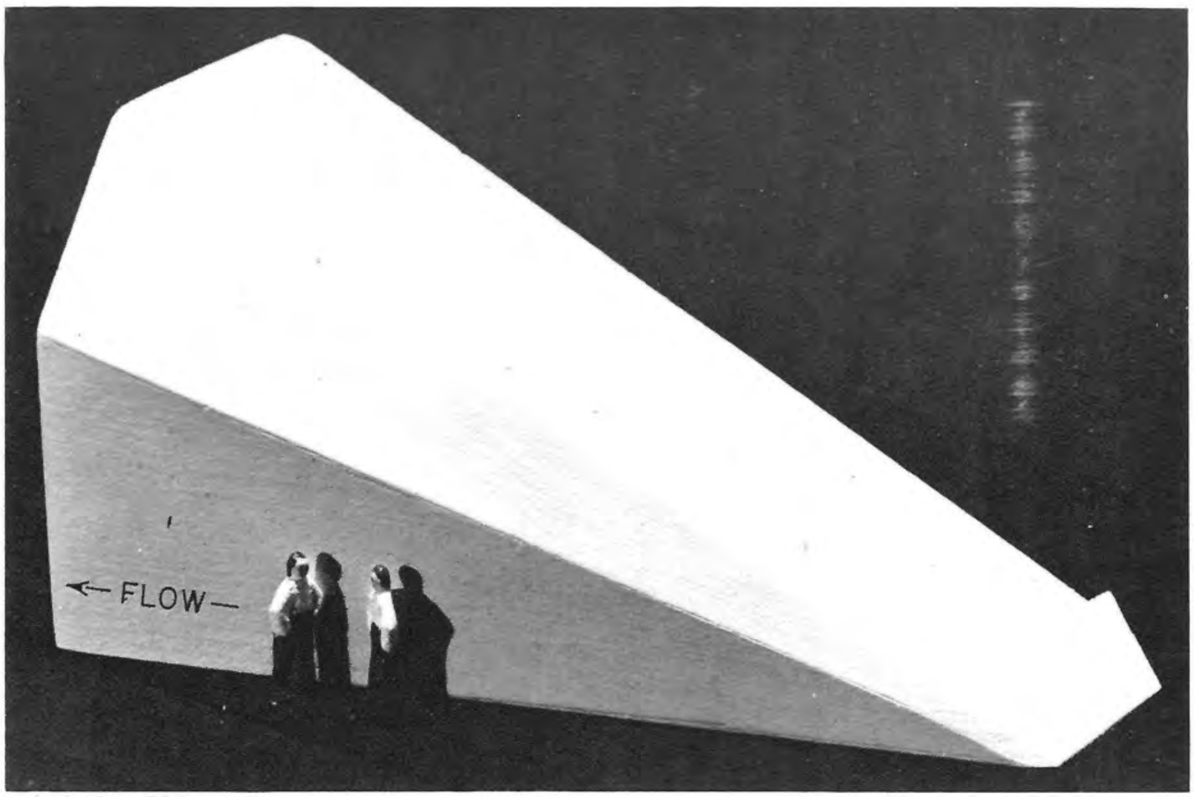
Tests to determine the erosive action and tailwater interference conditions when the spillway jet impinges on the Feather River indicated that large sand bars would form in the river at a spillway discharge of 150,000 cfs or greater. The tailwater interference tests showed that the powerplant tailrace would not be affected by spillway discharges up to 75,000 cfs; from 75,000 cfs to 150,000 cfs the tailwater would increase the water surface elevation up to 7 feet; at flows above 150,000 cfs the powerplant would not be operating.

Studies for the Office of Saline Water

Roswell Plant.--Assistance in conducting performance tests of the Roswell plant was continued this year. A special pitot tube for measuring relatively high-velocity waterflows at high temperatures was constructed by the laboratory shops. This tube and the Venturi-type probe sent to Denver from Roswell, New Mexico, were calibrated over the range of flow velocities to be experienced, and were shipped back to the Roswell plant. Subsequently, an engineer from the Hydraulics Branch traveled to Roswell to assist in measuring liquid flow velocities within the Second Effect evaporator at full operating temperatures and in analyzing the test data. He returned to Denver after approximately half of this test program had been completed when it became necessary to shut down the plant for an unknown period. The tests were continued by the Roswell personnel after operation was



A. Overall view of final model. Discharge 150, 000 cfs.



B. One of four large sloping blocks placed at the end of the chute to disperse the flow.

Figure 8. Oroville Dam flood control outlet model, 1:78 scale.

resumed. When measurements were attempted at the entrance to the conic expander under the lower tube sheet, the stem of the measuring probe bent severely. In removing the probe, the sensing head was damaged and a new one was requested in a telephone call from Roswell to Denver. The new pitot tube was constructed, calibrated, and shipped to Roswell so the test program could be completed.

Review of 50-mgd plant conceptual designs.--In response to a request by the Office of Saline Water (OSW), the Bureau of Reclamation is providing technical review for fifteen 50-mgd conceptual design studies of a multistage flash evaporator installation. The purpose of the studies is to determine the present "state of the art" in flash evaporator design and to obtain reasonable cost estimates for an installation which could be built within the limits of the present technological knowledge. The Hydraulics Branch was requested to critically examine the hydraulic design and vapor separation phases of each conceptual design study. The workability of the proposed design and delineation of possible problem areas are the prime considerations. Fifteen conceptual designs were submitted to the Hydraulics Branch and examination of their hydraulic aspects is complete.

San Diego saline water test facility.--A laboratory study was started on a pump intake manifold for the circulating pumps. To adequately evaluate the various factors affecting the flow in the intake manifold a 1:8 model was designed to verify, or if necessary, modify the design of the Fluor Company, such that it would be essentially free from vortex formation and excessive drawdown of the water surface in the evaporators. Flow rates in the manifold are variable and it is essential that a net positive suction head be maintained on the circulating pump, free of vapor-entraining vortices.

SECTION IV--ASSISTANCE TO FOREIGN GOVERNMENTS

The Hydraulics Branch continued its assistance to foreign governments this year. It continued a laboratory study for the British Columbia (Canada) Hydro-Authority on the outlet works for Portage Mountain Dam. A study was started on the spillway modification for Patillas Dam, Puerto Rico. Assistance continued to be rendered to Mr. K. S. Pathak, Engineering Attache for the government of India, in connection with Beas Dam. In addition, the Branch provided on-the-job training for 6 engineers from other countries and was host to 1 foreign observer and 39 foreign visitors.

Portage Mountain Dam Outlet Works

Portage Mountain Dam is part of the Peace River hydroelectric project located in northern British Columbia about 80 miles west of Dawson Creek and 480 miles north of Vancouver.

Peace River will be diverted, during construction, through three 2,500-foot-long, 48-foot-diameter horseshoe-shaped concrete-lined tunnels. Later, two tunnels will be modified to operate as low-level outlets. The third tunnel, with cross connections, will provide access to the other two. The low-level outlets, with a capacity of 10,000 cfs at reservoir elevation 2125, will control the reservoir level during filling and serve as standby outlets thereafter.

The original low-level outlet works design, utilizing two jet-flow gates per tunnel, was tested in a 1:24 scale model. The model study indicated that an extensive stilling basin would be required to effectively dissipate the energy of the flow. Therefore, jet-flow gates were abandoned and Howell-Bunger valves were substituted. These valves placed at the downstream end of the tunnel plug conduits (two in each tunnel) were installed in a 1:14 scale model of Diversion Tunnel No. 2 (Figure 9). The primary purpose of the model study was to develop a satisfactory means of dissipating the energy in the jets from the valves and to develop a satisfactory air-venting system.

An air vent was developed to draw air from a point in the crown of the diversion tunnel 210 feet downstream from the tunnel plug face, through a 10-foot-diameter flat bottom horseshoe tunnel, to the crown of the valve chamber at the tunnel plug. The size was determined by first measuring the amount of air required to maintain the pressure in the valve chamber at or above a subatmospheric pressure of 2 feet of water; and then, by limiting the air velocity in the tunnel vent to 100 feet per second to determine the cross-sectional area required.

Several arrangements of the energy dissipating devices in relation to tunnel liner size, valve location, and tailwater depth were investigated. It was determined that the size of the tunnel liner, the valve spacing,

A. Side view.

B. View looking directly upstream.

Figure 9. 1:14 scale model of Portage Mountain Dam low-level outlet works.

or the distance of the valves above tunnel centerline are not critical, within limits, from a hydraulic performance standpoint; whereas, the tailwater depth is very critical. Therefore, the minimum tailwater depth within the tunnel was determined in conjunction with the minimum number and size of energy-dissipating devices; namely, baffle piers and ring deflector. To provide the required tailwater within the tunnel, a control weir was constructed at the diversion tunnel portals.

Pressures were recorded on the baffles, ring deflector, and walls of the liner to aid in the structural design of the structure.

The three-man consulting panel for the Portage Mountain Development met in Denver on February 28, 1966, with representatives of IPEC and the British Columbia Hydro-Authority, to observe the model of the Portage Mountain low-level outlet works and to review test data.

A hydraulic laboratory report of the entire investigation is being prepared.

Patillas Dam Spillway

A 1:36 scale model of the Patillas Dam spillway was constructed in the laboratory. The dam is an existing structure in Puerto Rico and has discharged spillway flows over the years that have resulted in a considerable amount of erosion in the natural channel at the downstream end of the spillway. The studies are being made to find an alternate spillway design that will eliminate this adverse condition. The present spillway is an automatic flashboard-controlled crest 252 feet long that is designed to discharge into two hourglass-shaped chutes that fit the natural contours of the topography. The spillway chutes drop approximately 100 feet in elevation from the crest and merge at their downstream ends. Presently, there is no energy dissipator or flip bucket at the toe of the chute, which probably accounts for the excessive erosive tendencies of the flow.

It is planned to modify the existing structure over a period of several years so that it will eventually be capable of discharging the required quantity. The first phase will be to improve the badly eroded downstream river channel and to slightly modify the spillway and chutes so that the structure will handle 50,000 cfs. For the final design, which will be accomplished in three or four phases, the spillway crest will be lowered 5 feet, wider gates will be installed, and the spillway chute further modified. The effectiveness of each stage of the modifications will be determined in the 1:36 scale model which will eventually be used to determine the final recommended design.

On the basis of the initial model studies, a proposed spillway design for increasing its capacity from the existing 20,000 to about 90,000 cfs is being developed. However, a hydraulic jump basin may be required

Figure 10. A 1:36 scale hydraulic model of the Patillas Dam spillway is being studied to improve the capacity and safety of the structure.

to prevent excessive erosion at the downstream river channel; this would require a more extensive structure. Pending a decision on the type of structure required, model studies were suspended in May 1966, to be resumed following a draft of the design.

Foreign Trainees

Rafael De Gracia	Rep of Panama	6-18-65 to 8-27-65
Abdul Tawab Assifi	Afghanistan	6-21-65 to 9-10-65
Chalerm Tangtrongjit	Thailand	1- 3-66 to 1-14-66
Sakir Bekem	Turkey	3-21-66 to 4- 1-66
Sunthorn (Tom) Rungrongthanin	Thailand	4- 4-66 to 10- 1-66
Benjamin C. Mercado	Philippines	4-18-66 to 4-21-66

Foreign Observer

W. K. Clark	New South Wales, Australia	5- 3-66 to 5- 5-66

Foreign Visitors

Prof. Takusuke Yonemoto	Tokyo, Japan	7- 2-65	1 day
Dr. S. R. Singamsetti	India	7- 6-65	1 day
Fong-Yih Liu	Taipei, Taiwan	7- 6-65	1 day
J. E. Nash	Galway, Ireland	7- 8-65	1 day
Basilio Espildora	Chile	7- 9-65	1 day
Chia-Kuei Yen	Taiwan	7-13-65	1 day
Mr. Arenas	Argentina	7-16-65	1 day
Mr. Sawai	Japan	7-22-65	1 day
Messrs. Bhatti) Rava) Ida) Toyokura)	Japan	8-30-65	1 day
Takaoki Itakura	Sapparo, Japan	8-31-65	1 day
Colan Blow	New Zealand	8-31-65	1 day
Gordon Hill	Canada	9- 2-65	1 day
Al Peterson	Alberta, Canada	9- 9-65	1 day
Albert E. Stohr	Victoria, Australia	9-16-65	1 day
Mr. Lam Van Loi	Vietnam	9-20-, 21-65	
Geraldo Q. Siqveir	Sao Paulo, Brazil	9-22-65	1 day
Eduardo F. Oliveira	Sao Paulo, Brazil	9-22-65	1 day
Jose L. Leitao	Lisbon, Portugal	9-28-, 29-65	
M. J. Schnitter	Switzerland	10-15-65	1 day
Dr. J. Huder	Switzerland	10-15-65	1 day
R. A. Ribi	Switzerland	10-15-65	1 day
L. S. Herbert	Australia	11- 3-65	1 day
Henry Ham	Vancouver, Canada	11-15-, 16-65	
Jack Forster	Vancouver, Canada	11-15-, 16-65	

Foreign Visitors--Continued

David Bredenkamp	Pretoria, South Africa	11-16-65	1 day
R. W. Lockie	Vancouver, Canada	1-14-66	1 day
Abdul Ghaffar	West Pakistan	1-24-66	1 day
Mohammad Akram Khan	West Pakistan	1-24-66	1 day
Nazir A. Goraya	West Pakistan	1-24-66	1 day
Mirza Muhammad Munir	West Pakistan	1-24-66	1 day
Dr. S. P. Mao	Taipei, Taiwan	3-16-66	1 day
Prof. Fumio Ambo	Japan	4-11-66	1 day
Eero Kajosaari	Finland	5-11-66	1 day
Dr. Taduesz W. Manthey	Gdansk, Poland	5-13-, 17-66	
Ralph G. West	Wallingford, England	5-24-66	1 day
R. B. Dowdell	Wallingford, England	5-24-66	1 day

SECTION V--HYDRAULIC INVESTIGATIONS

This section contains material descriptive of the current research studies and the projected program for the Hydraulics Branch. Much of it is first draft of material prepared upon request of higher headquarters.

A. Outline of Proposed Program of Water Resources Engineering Research, Hydraulics Branch, Fiscal Years 1967-1976

B. Hydraulics Research Projects--Accomplishments in FY66 and program for FY67

C. Lower Cost Canal Lining Program

D. FY68 Narrative Justification for Water Resources Engineering Research (Hydraulics Branch)

E. General Investigations Control Schedule FY67-FY72

F. Commentary on Significant Developments in Hydraulics Research

A. OUTLINE OF PROPOSED PROGRAM OF
WATER RESOURCES ENGINEERING RESEARCH
HYDRAULICS BRANCH
FISCAL YEARS 1967-1976

SUBJECT	FISCAL YEAR 67	68	69	70	71	72	73	74	75	76	REMARKS
A. HYDRAULIC RESEARCH											
1. ENERGY DISSIPATORS											
a. Hollow-jet valve basins	X										
b. Vertical stilling well	X	X									
c. Type VI basin	X										
d. Prototype studies	X	X	X	X	X	X	X	X	X	X	
e. Sudden enlargement	X	X	X								
f. Vortex basin	X										
2. GATES, VALVES AND ORIFICES											
a. Air demand	X	X	X	X	X						
b. Hydraulics of slide gates	X	X	X								
c. Orifice controls for automatic gates	X										
d. Gate seals	X	X									
e. Butterfly torque		X	X								
3. PIPELINE AND TUNNEL HYDRAULICS											
a. Surges in pipelines	X	X									
b. Resistance coefficient measurements on operating power & irrigation conduits	X	X	X								
c. Stability of submerged conduits		X	X	X							
4. INSTRUMENTATION, DATA ACQUISITION AND COMPUTER TECHNIQUES											
a. Instrumentation	X	X	X	X	X	X	X	X	X	X	
b. Computer techniques	X	X	X	X	X	X	X	X	X	X	
5. FLOW SURFACE PROTECTION											
a. Surface tolerances	X										
b. Cavitation tendencies of free jets	X	X									
c. Prototype observations	X	X	X	X	X	X	X	X	X	X	
6. OPEN CHANNEL HYDRAULICS											
a. Inlet and outlet transitions (Prototype)	X	X	X	X							
b. Riprap studies	X	X	X								

NOTES:

SHEET 1 OF 2

OUTLINE OF PROPOSED PROGRAM OF

WATER RESOURCES ENGINEERING RESEARCH

HYDRAULICS BRANCH

FISCAL YEARS 1967-1976

SUBJECT	FISCAL YEAR 67	68	69	70	71	72	73	74	75	76	REMARKS
A. HYDRAULIC RESEARCH (cont.)											
7. INTAKES, ENTRANCES AND TRANSITIONS											
a. Draft tube studies	—	—									
b. Hydraulics of intakes	—	—	—								
8. QUALITY OF WATER AS AFFECTED BY STRATIFIED FLOW											
a. Bibliography	—	—	—								
b. Effect of res. geometry & tributary waters on temp. stratification	—	—									
c. Determination of selective withdrawal techniques		—	—	—							
B. WATER MEASUREMENT RESEARCH											
I. WATER MEASUREMENT											
a. Evaluation and Exploration											
I. Radioisotopes	—	—	—								
II. General device	—	—	—	—	—	—	—	—	—	—	
b. Interpretation of various techniques for Bureau needs	—	—	—	—	—	—	—	—	—	—	
c. Acoustical meter tests	—	—	—								
C. AQUIFERS, DRAINAGE, SEEPAGE AND SEDIMENT RESEARCH											
I. AQUIFERS AND DRAINAGE											
a. Salinity displacement	—	—	—	—							
b. Effects of permeability (Drainage)	—	—									
2. SEEPAGE											
a. Measurement of seepage losses	—	—	—	—							
3. STABILITY OF CHANNELS	—										

NOTES:

SHEET 2 OF 2

B. HYDRAULIC RESEARCH

1. Energy Dissipators

Extremely high energy forces in flowing water have always been of concern in the design of hydraulic structures. To effectively contain or dissipate these excess forces before the water is discharged into the downstream channel is one of the greatest areas of uncertainty in the design of water conveyance systems.

The objective of this research is to develop the many possible types of energy dissipators, including hydraulic jump, stilling wells, impact-type stilling basins, flip buckets, sudden enlargements, plunge basins, and baffled aprons for general use so that future laboratory developmental work on individual structures will be a minimum.

Of primary need are hydraulic jump stilling basins for overfall spillways or canal drops. Five types of hydraulic jump basins have been developed and generalized so that they may be designed for most combinations of head, height of fall, and unit discharge. Four other types of energy dissipators have been developed such as roller buckets, impact-type basins, flip buckets, and baffled aprons for use where hydraulic jumps are not feasible. Special-purpose stilling basins such as vertical stilling wells, turbine-type, and sudden enlargements as used with outlet works controlled by gates and valves, are being developed. A series of progress reports have been issued on various phases of the overall program.

The use of sudden enlargements downstream from gates or valves offers an economical solution to specific installations if the potential for damage by cavitation could be eliminated or reduced. Tests are needed to evaluate schemes whereby cavitation effects are minimized by using sudden enlargements and by admission of air. Design parameters for determining the cavitation index and general performance of specific types of control devices should be developed for general use.

This continuing program will be directed toward completion of the following items:

a. Hollow-jet valve basins
b. Vertical stilling well
c. Type VI basin
d. Sudden enlargement
e. Prototype studies

Accomplished 1966

Laboratory studies were made to duplicate the damage in a prototype hollow-jet valve stilling basin operating under nondesign conditions; the same facility was used to determine modifications to a damaged prototype basin. Exploratory tests were made on the model vertical stilling well and a test program was formulated. Investigations were continued on a sudden enlargement energy dissipator downstream from a butterfly valve. Initial tests were made to determine pressure measurements on baffle piers in stilling basins. Studies were continued to determine possible design alterations to overcome the weed-clogging problems on the Type VI basin.

Test equipment was installed in the center wall of the Yellowtail Dam outlet works stilling basin for making pressure and accelerometer measurements. Measurements were made in November 1965 for flows of 150 and 500 cfs through one side of the basin containing an 84-inch hollow-jet valve evacuation outlet. The unbalanced pressure force, caused by the 500-cfs flow, was less than 0.5 psi, and no wall movement was indicated by the accelerometers.

Pressure transducer and accelerometer measurements in the outlet works stilling basin were again performed in December and January. The December series of measurements covered a discharge range of 1,000 to 2,000 cfs, and the January measurements covered a range of 2,250 to 3,100 cfs. The approximate maximum change in pressure on the center wall was 30 feet of water for the 3,100-cfs discharge. No movement of the center wall was apparent from recordings of the output of the accelerometers.

Before the start of this test series, 12 pieces of rock, forming a part of the riprap slope downstream of the basin were numbered and their position was recorded. These rocks have been observed during the test series, and it was noted that a few had been disturbed by waterflow.

Scheduled FY67

Investigations on the hollow-jet valve stilling basin will be continued to determine causes for debris being drawn into the basin and methods of prevention. A report will be prepared on the narrow-deep slide gate stilling basin. Investigations on the vertical stilling well will continue. Modifications to the Type VI stilling basin will be recommended. The program for installing instrumentation and obtaining pressure, vibration, and surge measurements in prototype energy dissipators will be continued.

2. Gates, Valves, and Orifices

Frequently, cavitation and vibration of gates and valves can be prevented through admission of air. The required size of the air vent can be determined for cases in which a hydraulic jump forms in the downstream conduit and for a falling water surface. However, empirical relationships are required for various other downstream conditions such as high-velocity flow in a conduit flowing partially full, spray downstream from a slide gate operating at small openings, and flow from a Howell-Bunger valve. In addition, model and prototype comparison is required to verify the empirical relationships.

During the operation of slide gates at partial openings, hydraulic downpull forces tend to close the gate; to properly design hoists and gate supports, knowledge of these forces is necessary. The variables which require investigation include various ratios of gate thickness to lip extension, effect of recesses in the well above the gate leaf, effect of gate slots, effect of aeration on pressure distribution, and gate seal shape and location. Data for specific cases have been compiled from laboratory and field tests and are presented in laboratory reports and technical papers. Further laboratory and field investigations are necessary to establish the effects of placing the gates at the face of an entrance, within the entrance, or within the main conduit itself.

Flared or divergent side walls frequently are used downstream from slide gate installations. Although these walls are beneficial in spreading the jet, severe subatmospheric pressures and cavitation may occur on the surfaces where the divergence starts. Tests are needed to determine the severity of negative pressures for various rates of divergence, the maximum operating heads that are permissible, and design changes that might be used to avoid or minimize the low pressure tendencies.

The regulation of reservoir elevations is frequently achieved through the use of spillway gates automatically controlled by floats in stilling wells. To maintain the correct gate opening for various reservoir levels requires that the flow through the intake from the reservoir to the stilling well be accurately controlled. In recent years, orifices have been used to control the intake flow. Discharge coefficients for orifice plates in unusual settings and for circular openings in pipe walls are needed to improve the design of automatic controls of spillway gates.

Improved gate seal design has been made possible through recent developments in synthetic materials and in bonding procedures. Studies of seals, seal-clamping arrangements, seal gaps, and seat designs are needed to meet the demand for better sealing under difficult situations.

The control of reservoir elevations and flow rates over spillways is frequently achieved through the use of radial gates. The most efficient use of these gates requires that the rate of flow passing the structures be known to a high degree of accuracy. The wide variety of structural shapes and the numerous physical dimensions, shapes, and settings of the gates combine to create an infinite number of combinations affecting flow rate. Empirical data to evaluate these variables for specific installations are being generalized.

Anticipated future research needs include the investigation of the torque required to close a butterfly valve, investigation of the effect of gate slot and slide gate shapes on the production of spray with small gate openings, and consideration of the mechanics by which droplets of water create air movement.

Accomplished FY66

Analytical studies of air vent sizes and air demand are essentially complete for the Morrow Point Dam Powerplant intake structure. A computer program was written to compute both the quantity of air flowing into a gate chamber and the gate chamber pressures for the case of a falling water surface in the chamber. A draft of a report describing these studies was started. Equipment was received and construction begun on a facility for testing 12-inch sections of prototype gate seals at heads up to 600 feet. This facility can be operated with or without relative motion between the seal and the gate seat. A configuration for diverging or parallel walls downstream from a slide gate which was essentially free from subatmospheric pressures was determined. The configuration consisted of a sudden offset away from the flow as near the downstream edge of the gate slot as is structurally possible. Discharge coefficients were obtained for orifices in circular planes. In addition, discharge coefficients were obtained for orifices with irregular upstream and downstream piping arrangements.

Scheduled FY67

Analytical, model, and prototype studies on air demand will continue. Determination of air flow quantities over a rapidly moving water surface in a partially filled conduit will be emphasized. Dimensionless plots of air demand versus pressure will be analyzed for Howell-Bunger valves. Operation of the gate seal test facility will be initiated. The effect on the pressure distribution of a vertical curve in the conduit upstream from a slide gate will be investigated. The orifice studies will be completed and a report combining the results will be prepared.

3. Pipeline and Tunnel Hydraulics

Check towers, pipe stands, and air relief structures are often constructed in long pipelines. When properly designed and installed, such appurtenances prevent high operating heads and permit the use of relatively lightweight, inexpensive conduit. When filling, draining, or operating at other than design discharge, surging can develop in an improperly designed pipeline and create damaging overpressures and other objectionable operating difficulties. The proper size and shape of towers, stands, and air vents can be determined analytically and by scale model studies; however, analytical or model determination of the proper location of these structures to prevent surging is a more complex problem. A computer program to perform the tedious computation of the general problem of surging in long pipelines is being developed. Various random surging situations will be established in a laboratory model, and the results of the pressures, discharges, and flow direction with respect to time will be used as "input data" to check, correct, and refine the computer program.

Theoretical analysis of surface resistance head loss does not completely describe nor define the coefficients required to determine the size of conveyances. In determining the size of conduits, the predominant factor is the shear of the fluid at the solid boundary interface. Thus, increases or decreases in surface roughness caused by construction methods produces a corresponding change in the boundary shear. The size and cost of the conduit become dependent on the accuracy of prediction of the surface roughness. Measurements on constructed Bureau conduits provide the necessary correlations between the theory and experimental values of surface resistance head loss. These measurements are a part of the studies providing design information.

Accomplished FY66

Hydraulics Branch Report No. Hyd-555 regarding the shape, flow characteristics, and hydraulic losses of the check tower and the size and location of an air vent to remove air downstream from the tower in the Canadian River main aqueduct was published.

A new control valve for the surge model was developed and installed. This valve will permit uniform increments in discharge with respect to time for model elapsed time from 300 to 3,000 seconds for zero to full discharges. Thus, the model will more nearly duplicate expected prototype behavior and simplify obtaining check data for the ADP program. A new program for the Honeywell computer was written.

Pressure fluctuations were measured in three of the distribution laterals of the South Gila Unit near Yuma, Arizona. The laterals constructed of cast-in-place concrete pipe have cracked circumferentially and longitudinally. The measurements were made to determine if pressure fluctuations, caused by operating procedures, were a possible cause of the cracking. Measurements of pressure surges in the laterals were made during the filling of the laterals and for rapid closures of delivery valves that had been discharging up to 133 percent of design flow. Pressure transducers were placed directly in the water in the pipe, connected to piezometers and to the delivery valves. Continuous charts were used to record the rate and magnitude of the fluctuations of pressure. Good records were obtained in the test series and the pressures were apparently within design values. The tests showed that neither the static nor dynamic hydraulic pressures were sufficiently large to cause the failures of the lateral pipe.

A capacity test was planned and a part of the measurements were performed to determine the capacity of the Salt Lake City Aqueduct.

The aqueduct is about 47 miles long and contains a series of concrete pipe sections, tunnels, and inverted siphons. There has been an indication that the total flow through the aqueduct would exceed the design value and the measurements were requested to establish the amount. Measurements for one discharge of 150 cfs were completed before operational difficulties stopped the tests. More tests are planned for July of 1966. Completion of the test program will provide information on the aqueduct capacity and surface resistance coefficients for several long concrete-pipe siphons.

Scheduled FY67

Model data for various control gate opening speeds, with uniform distances between check towers, will be furnished for debugging the new ADP program. Model configuration will be changed to include nonuniform distances between check towers and with selected check towers replaced with surge chambers. Data for these two conditions will be furnished for further ADP refinement.

4. Instrumentation, Data Acquisition, and Computer Techniques

The study of steady and unsteady flow phenomena requires instrumentation for recording data accurately in short periods of time. Instrumentation for this purpose is being manufactured continuously and can be adapted to provide precise measurements. Selection of the instruments is partly controlled by the method of data analysis. Both digital and analog methods are used for analysis of the data. Thus, the purpose of this program is to study modern instrumentation and analysis methods to improve our applied research investigations.

Accomplished FY66

Investigations were intensified by use of equipment obtained after study of available instruments. New capability for accurate pressure measurements resulted from the use of a precision force balance system and integrating digital voltmeter. The force balance provided a resolution of pressure not formerly possible. Both precise instantaneous pressures and an integrated value of the pressure became available by combining the balance and voltmeter. An analog or digital recording of the pressure signal is available for use in data analysis. Components of signal conditioning equipment, analog or digital output, and means of conversion of one form to the other may be combined in systems for versatility. Use of these systems helps us to define requirements for system that will reduce the time necessary for acquiring data and for analysis after acquisition.

Components were acquired for a pressure transducer calibration system; a precision air deadweight tester and pressure volume controller. These instruments with a manifold piping system will be used to accurately calibrate transducers for multipoint pressure investigations. Both the precision and speed of calibration will be increased to provide more and better information from hydraulic studies.

A more detailed analysis of velocity fluctuations became available through the purchase of a hot-film anemometer. The sensor probes coated with a thin layer of quartz can be used for turbulence studies in both air and water. A small wind tunnel was obtained for calibration of the anemometer.

A digital quartz thermometer for accurately measuring temperatures was studied and later purchased for use in stratified flow and discharge measurement investigations. Modulation of the oscillating frequency of the quartz crystals can be precisely related to the temperature change.

A study of frequency-modulated magnetic tape systems was made and specifications for a system were written. Purchase of the system at a later date will increase our capability for acquiring both laboratory and field data in multiple channels.

A frequency analyzer was obtained to increase our understanding of the nature of pressure and velocity fluctuations. The analyzer, coupled directly to a pressure transducer or a magnetic tape loop system, will provide information on the frequency spectrum and the energy involved in frequency band.

Signal conditioning and calibration equipment for various types of transducers were obtained to improve the use of data acquisition systems.

A contract was awarded for a medium-size analog computer for Research Division use. Analog computers are especially well suited for the time solution of specific types of mathematical equations, for simulation of physical systems and/or subsystems, and for the control of physical processes. As the Research Division often constructs models to simulate physical systems and at present is actively studying control systems, the analog computer is especially well suited to such needs. The computer will have 50 operational amplifiers, 16 integrators, 70 coefficient setting potentiometers, and much additional physical equipment. An X-Y recorder for the computer was purchased also. A training program for use of the computer was outlined and organized.

Studies concerning a real-time data collection, data reduction, and control system continued and a report which provides backup material for establishing tentative requirements and criteria for a real-time computer control system was prepared.

Digital computer use continued to increase throughout the year and 17 additional engineers were trained to program the digital computer during fiscal year 1966.

Preliminary tests were completed to investigate the dynamic response characteristics of several typical pressure line lengths and types which were connected to standard pressure cells.

Scheduled FY67

A broader application of instrumentation will be studied to increase the quantity and quality of data acquired from the models. Research will be continued to provide instrumentation compatible with the data acquisition systems for use with computers. Investigations of available commercial equipment will be continued to gain a knowledge of the availability and capability of supplying the needs of our investigations. A pressure calibration system for transducers will be completed to assure an accurate measurement of pressures. Upgrading of the laboratory and model control facilities will facilitate the use of newer and refined instrumentation systems for which studies will be made.

The dynamic characteristics of pressure line lengths connected to standard pressure cells used in the Hydraulics Branch will be analyzed and a report describing the results will be published.

A training course on use of the analog computer will be conducted. The course will be conducted by Research Division staff members and will train 12 Research Division engineers to program and operate the new analog computer. The training will start soon after the beginning of the new fiscal year and will require about 40 hours per man.

Requirements for a real-time computer control system will be compiled. If review is favorable, invitations for manufacturers' proposals will be issued. Proposals will be reviewed and installation of the system will be started.

Training in digital computer use will continue as required.

5. Flow Surface Protection

Flow surfaces in spillway and outlet works subjected to high velocities must be protected against damage by cavitation erosion. This protection may take the form of proper surface configuration to prevent cavitation, close tolerances and stringent specifications regarding alinement and surface texture, protection by admitting air to the cavity, or the use of a material resistant to cavitation damage. A thorough knowledge of the cavitation tendencies of various surface irregularities is needed to determine the most effective and least expensive method of correcting or protecting flow surfaces to prevent damage to structures. Much of this knowledge can be gained in the laboratory in a high-velocity water tunnel test facility. Representative joints, humps, offsets, and depressions can be placed in the apparatus and subjected to high-velocity flows and low pressures. The pressure-velocity combinations that produce cavitation can be determined for each shape tested, and cavitation index values obtained. Studies to date have established such parameters for several offset shapes protruding into the flow.

The boundary layer thickness of flow affects the velocities, and therefore, the cavitation potential that exists at an offset or irregularity in a flow surface. A knowledge of the rate at which the turbulent boundary layer develops downstream from gates and valves is required to properly evaluate the cavitation potential of irregularities of flow surfaces in hydraulic structures.

Air entrained in flowing water acts as a cushion against the damaging action of cavitation. In an environment where air was purposely admitted to an area of cavitation damage (Grand Coulee Dam outlet works), the damaging potential was eliminated. More information is needed about the amount of air needed to prevent damage, the method of introducing air into the stream, or the optimum location of air admission.

Knowledge of the location and extent of damage recently observed at Glen Canyon Dam outlet works will serve as a guide to determine the shapes, flow conditions, and air admission to be tested in the water tunnel test apparatus.

Accomplished FY66

Preliminary tests were performed in a model with an open rectangular flume downstream from a high-head slide gate. Attempts to determine the cavitation potential of into-the-flow offsets protruding from the floor of the flume were inconclusive.

The 4-inch-wide by 6-inch-deep water tunnel with full length side windows was rehabilitated for continued cavitation studies.

Areas damaged by cavitation at Glen Canyon Dam were studied to ascertain the source of the cavitation.

Scheduled FY67

Tests in the water tunnel will be made and photographically recorded to determine discontinuity limits for irregularities causing cavitation damage at Glen Canyon Dam. A more sophisticated open flow apparatus will be constructed, based on knowledge gained from tests in the closed water tunnel concerning flow pattern, boundary layer effect, and air demand. Analytical studies coupled with experimental data will be continued to define the boundary layer formation and its effect on cavitation at surface irregularities.

6. Open Channel Hydraulics

Although flow velocities in open channels are usually very low, efficient energy dissipation and flow distribution are essential to prevent undercutting and damage to canal structures such as drops, turnouts, wasteways, overchutes, culverts, transitions, and bifurcations. In addition, minimum head losses at these structures are necessary to insure an economical and efficiently operating system.

Verification of model studies with field tests on a number of individual designs is required. Whenever possible, the design should also be studied analytically to develop general methods for design computations.

Field measurements indicate that present design procedures are not entirely adequate to account for the effects of size, alinement, and aquatic growths on the flow capacity of large canals. The measurements substantiated field reports of operational difficulties and emphasized the need for research and testing to develop improved methods of determining flow resistance.

The extensive use of upstream water supplies has resulted in excessive salt water intrusion and a reduction in the quantity of usable fresh water available in estuaries. Laboratory studies on river hydraulics and tidal transients in estuaries are needed to determine methods to prevent contamination of fresh river water by sea water intrusion.

The use of large pumping plants on some Bureau projects has brought up the problem of designing the approach channel to contain the bore wave or surge that will be propagated if the pumps should suddenly stop. A knowledge of the celerity and growth of these surges is necessary to obtain an effective and economical method of reducing their magnitudes.

Design of size of riprap and thickness of a riprap blanket to use for bed and bank protection against scour has been a difficult and baffling problem for many years. Invariably, a rule of thumb or an experience factor must be resorted to in solving this type of design problem. Laboratory studies are needed to develop criteria upon which the design of riprap protection can be based.

Future research needs include further verification of model tests with prototype measurements on culverts, transitions, drops, and bifurcations.

Accomplished FY66

An analytical study of a flow junction was compared with a model study. The junction served to unite flows from a canal and an inverted siphon and direct the combined flow into a tunnel. A report of the study (Hyd-551) was published. Studies were conducted on two canal sections to determine characteristics of rejection surges. A longitudinal side weir was tested for the attenuation of a pumping plant rejection surge. Studies continued for various weir lengths. A laboratory report (Hyd-546) covering this subject was published.

A nominal amount of data was derived from studies on large canals to determine effects of weeds and algae on resistance to flow. Also, discussions were held with Region 2 representatives on laboratory techniques to determine roughness values for sponges and clams in open channels.

Plaster casts of sponges and clam sediment deposits were made and sent to Denver. Study of the casts showed that measurements of surface resistance coefficients would not give meaningful results. No tests are planned for the samples.

Report No. Hyd-521, "Aerodynamic Study of Concrete Surface Roughness for Canal Capacity Program," was published. The report describes the results of a closed-conduit study of a concrete surface to measure the surface roughness. Physical, velocity distribution, and shear measurement methods were used in correlating physical roughness and fluid dynamic roughness.

Scheduled FY67

A report describing the characteristics of rejection surges will be prepared. Studies will be made to determine the relationships between size of uniform and of graded riprap and the flow of water at various velocities under a gate. A baffle gate mounted on a movable carriage in an existing test facility, consisting of an 8-foot-deep by 4-foot-wide by 70-foot-long flume, will be used. Data will be taken to compare the depth of scour under the baffle gate for several shapes, sizes, and gradations of riprap with discharge under the gate, differential head across the baffle gate, and depths upstream and downstream from the gate.

7. Intakes, Entrances, and Transitions

Surging in draft tubes has resulted in poor operational characteristics for many powerplants and, in some cases, has restricted power output. Studies of basic flow properties in draft tubes are required to eliminate or reduce the tendency for surging and to permit a more compact arrangement in underground powerplants.

Studies are also needed to determine the performance of the newly designed 135° pump intake elbows as draft tubes. Draft tube-type service will be encountered on some new pumping units that operate both as pumps and as turbines.

Entrances to penstocks or outlet pipes are normally streamlined and made as large as practicable to minimize entrance losses, to maintain positive pressures throughout, and to prevent formation of vortices which may reduce the capacity and entrain objectionable quantities of air. These entrances are often equipped with bulkhead gates which can be closed to unwater the conduit in cases of emergency. Costs of the gates and trashracks make it desirable to keep them as small as possible. Operation of several existing structures has indicated that the head loss at conduit entrances is comparatively small, and entrance size could be reduced with no loss in performance. Tests are needed to determine the actual losses at entrances of different sizes and configuration. These tests will be extended to determine minimum submergence required to maintain adequate pressures and to prevent vortices.

Accomplished FY66

An intensive review of the literature in several disciplines has been conducted in an effort to determine the basic flow properties in draft tubes. On the basis of this search, a model of a turbine scroll and conical draft tube has been constructed to correlate the empirical results with the theory. Data obtained from prototype measurements of a circular and a rectangular bellmouth at Glen Canyon Dam were analyzed to obtain the pressure factors which were compared with previously published model data. Hydraulics Branch Reports No. Hyd-509 and Hyd-510, which included studies on a sloping intake structure and a high-capacity sluice, were published. Hydraulic characteristics of an existing penstock intake and a proposed intake of greatly reduced size were analyzed and compared. Planning was started on a model study of the proposed intake.

Scheduled FY67

Investigations of various conical draft tubes will be conducted to determine an economical shape which will have the least potential for surging. Various surge suppressor configurations will be tested in the model to determine remedial corrections for existing facilities. A test facility also will be constructed to study vortex formation in multiple shallow submerged inlets to a manifold supplying water to a pumping unit in a reduced pressure environment. Plans will be completed and a model built of the proposed reduced size inlet. Studies will be started to determine head loss, pressure factors, necessary submergence, and other hydraulic characteristics of this low-cost inlet. Prototype pressure measurements of intake pressures will be obtained as opportunities occur.

8. Quality of Water as Affected by Stratified Flow

Problems of water quality control of vital concern are sediment movement in reservoirs, salinity of riverflows allocated to irrigation, and salinity intrusion in estuaries. Increasing attention also is being given to selective withdrawal of reservoir storage for control of downstream temperature and dissolved oxygen content. At certain times of the year, downstream water users require warm water for use in irrigating certain crops; at other times, cooler water during the fish-spawning season might be needed.

A library research program currently being conducted by the Hydraulics Branch indicates some areas which apparently have received little or no investigation. These areas include influence of reservoir and intake geometry on selective withdrawal and the optimization of intake design, model studies of particular reservoirs and correlation with prototype data, correlation of temperature distribution with dissolved oxygen in reservoirs, artificial alteration of density current distribution in reservoirs and estuaries, effects of hydraulic structures such as stilling basins on re-oxygenation of rivers, and effects of earthquakes on movement of water in reservoirs.

Accomplished FY66

A comprehensive bibliography of known research in stratified flow was prepared. A progress report, Hyd-563, which defines the present state of the art, was written. Construction of a laboratory test facility of temperature-initiated stratified flow was started. Special equipment and instrumentation were acquired.

Scheduled FY67

The library research will be continued to maintain a current bibliography. The laboratory studies and special instrumentation will be advanced.

B. WATER MEASUREMENT

9. Water Measurement

As water resources diminish, the need grows for improving water measuring methods, for increasing measuring accuracy, and for supplying information to people measuring the water. Distribution of water from older systems of canals and laterals requires an understanding of relatively simple measuring devices. New distribution systems demand a greater knowledge of complicated systems. More automation of water control and measurement increases the amount of knowledge required to assure the accounting for water to and from the distribution system. Studies from the water measurement program are planned to increase our knowledge of both the old and new devices and to tell others of the results.

Accomplished FY66

Reports and studies were completed on two different types of water-measuring devices. An 8-inch saddle-type propeller meter for use in pipes was studied for accuracy of registration. Two different pipe diameters, two pipe lengths upstream of the meter, flow straighteners, and the effect of an elbow were investigated in determining the water measurement accuracy of the meter. A punched-tape waterflow recorder for use in 12-inch pipe was studied for possible use in automatic billing of water users. The flowmeter is a tapered tube variable-area-type meter and records on punched paper tape. Use of this type meter in large turnouts in place of differential head meters has been considered.

Work continued on open-flow propeller meters with the construction of a test facility. Accuracy characteristics in nonconforming outlets will be investigated. Studies of trapezoidal measuring flumes were suspended pending completion of the report on a preliminary generalizing of the design. A literature search was made for information on the thermodynamic method of discharge and efficiency measurement. Sufficient information was found to continue an investigation of the use of the method for pumps and turbines.

A contract was made with Colorado State University to determine the effectiveness of natural turbulence of a developed velocity distribution to produce a uniform cross-sectional diffusion of a tracer introduced at some upstream cross section. The 800-foot-long 36-inch pipe facility of the University's fluid dynamics laboratory was utilized in this study in which Pontacyl Pink B dye was used as a tracer in the 36-inch pipe, and a Turner fluorometer was used to determine the dye concentration. The study is part of a comprehensive effort to determine the feasibility of using radioisotopes for measurement of flow in closed conduits. The study is supported in part by the Atomic Energy Commission.

Plans were made for measuring the flow of water through a turbine with radioisotopes during the acceptance tests planned for January 24, 1966, at Flaming Gorge Dam Powerplant. Although all of the studies necessary to define mixing characteristics, injection means, and the method of sampling have not been completed in either laboratory or field studies, the discharge measurements were planned to coincide with the turbine acceptance tests. A direct comparison could thus be made during these tests with the Gibson method of discharge measurement. Injection and sampling equipment were prepared and calibrated for these measurements to inject radioisotopes into the flow near the upstream end of the penstock and to sample near the entrance of the turbine. A high-head injection pump (9,000 millimeters per hour at 5,000 psi) was purchased for injecting the isotopes. The sample tank method was planned for use in determining the concentration of the radioisotopes after mixing the flow. These radioisotope discharge measurements could not be made during the acceptance tests because permission was not received from the State of Utah for the use of the radioactive tracer. The turbine measurement is still being considered. Tracer dispersion studies in an 8-inch pipe test facility are continuing in the Hydraulics Branch laboratory. Plans are being made to apply the results of the CSU and USBR dispersion studies to flow measurements at a Colorado-Big Thompson power or pumping plant.

Results from laboratory studies, field investigations, and technical literature on water measurement were assembled for use during the Irrigation Operators' Workshop. A comprehensive study of published information on Parshall flumes resulted in the rewriting of the material in a more concise and usable form. The compiled information on measuring devices will be offered at the Workshop to help improve the quality of water measurements in irrigation systems.

Scheduled FY67

Studies will be continued on conventional measurement devices as needed to improve Bureau water distribution practices. The program will include the evaluation of both open-channel and closed-conduit measurement devices and methods. Field tests of the application of radioisotopes for discharge measurements in turbines and pumps will be attempted. The acoustic, dye, momentum, and thermal methods will be evaluated in laboratory and field studies. Research results will be published and used for advising Bureau personnel responsible for water measurement.

C. AQUIFERS, DRAINAGE, SEEPAGE, AND SEDIMENTATION RESEARCH

10. Aquifers and Drainage

On many irrigation projects, ground water is becoming increasingly saline with time, and there is a definite need to understand more fully the movement of saline ground water when sweet irrigation water is applied to the surface of irrigated land. Previous studies of the behavior of fresh-water and sea-water interfaces in coastal areas and construction of flow nets indicate that selective drainage from two-part and one-part aquifers may not be practical. A 1:40 scale model of an idealized portion of the Gila Valley in Arizona was tested to determine the hydraulic action of tile drains placed 8 feet below the ground surface. An upper aquifer composed of fine sand and placed over a lower aquifer composed of coarse sand was tested in a tank 16 feet long, 2-1/2 feet wide, and 2-1/2 feet deep. Fresh water was applied to the upper aquifer surface, and the drain effluent was regularly sampled and analyzed to help determine the flow patterns in the model. The model was operated continuously for many days, keeping a continuous supply of fresh (irrigation) water flowing into the upper aquifer and a continuous outflow of drainage water from the drains.

The water table in some irrigated areas is maintained below the root zone by pumping from wells. Hydraulic model studies in a 4-1/2-foot-deep tank are being made to study removal of saline and/or fresh aquifer water by pump wells.

Accomplished FY66

Four tests to study removal of saline water from a two-part aquifer by well pumping were conducted in a 16-foot-long by 4-1/2-foot-deep by 2-1/2-foot-wide tank. The tests simulated drainage from an idealized portion of Gila Valley aquifer in Arizona, where the upper part of the aquifer, composed of fine sand, overlays a lower part composed of coarse sand. Electronic salinity-detecting equipment and an automatic recorder were used in making the measurements.

A paper, "Removal of Salt Water from Two-part and Single-part Aquifers Using Tile Drains," based on Hydraulics Branch Report No. Hyd-541, describing five tests of a two-part aquifer and five tests of a typical single-part aquifer of uniform fine sand made in a laboratory tank, was presented at the August 1965 ASCE Hydraulics Division Conference in Tucson, Arizona. A second paper, "Relaxation Methods Applied to Ground Water Flow Problems," describing a theoretical study of the two-part aquifer hydraulic model tests, was presented at the May 1966 ASCE Water Resources Engineering Conference in Denver, Colorado.

Data showing the change in salinity with time of the effluent from a pumped well drain in a two-part aquifer compare very closely with computed values of change in salinity of the effluent with time, which are based on previous investigations. A paper, "The Mechanism of Aquifer Sweetening," presented at the August 1965 ASCE Hydraulics Division Conference at Tucson, Arizona, gives the details of the analytical study.

Scheduled FY67

A report of the pumped well tests conducted in the laboratory tank of removal of saline water from a two-part aquifer will be prepared. Tests will be conducted using a 60-foot-long by 2-1/2-foot-high by 2-foot-wide flume to study the effect of drainage of sloping agricultural land on the spacing of tile drains.

11. Seepage

The cost of collecting and distributing new water on irrigation projects is becoming greater as more and more water is used and available water resources are more difficult to develop. Therefore, loss of water by seepage from canals and laterals on irrigation projects has caused concern. Losses from canals have been reduced historically by various types of watertight linings placed in areas where seepage losses are expected in new canals or are visually apparent on older canals. The problem of isolating leaking reaches having sufficient seepage to justify the cost of lining (lining of the entire canal is not necessary) is a difficult problem and needs further research to develop feasible and accurate methods. Electrical logging apparatus has shown some promise in detecting seepage in tests on field canals. Research studies in the laboratory and in a short, full-size test canal have shown that the logging equipment needs further development to be reliably accurate.

Seepage meters have been used to determine seepage losses in many full-size canals and in a test canal. Variation in seepage measurement results, obtained in comparatively short reaches of canals, indicates that the type of soil material and the presence of a surface film probably cause a variation in seepage rates. Different seepage rates in adjoining canal reaches also have been verified by ponding tests.

Accomplished FY66

Electrical logging tests were carried on in a flume, 4- by 4- by 32-foot-long, designed for seepage testing. Provisions were made to withdraw, at a uniform rate, water through a sand and gravel filter in the bottom of this flume. Both moving and fixed electrode studies using lead were completed in this test facility and resulted in inconsistent measurements of potential. Because of the differences encountered in previous tests using lead electrodes, nonpolarizing electrodes were used in the seepage flume tests.

Two types of tests were conducted with the nonpolarizing (Calomel) electrodes: (1) electrodes stationary and separated a fixed distance and (2) electrodes moving and separated by a fixed distance. Potentials generated in the sand bed by controlled seepage outflow were measured on a precision recording voltmeter.

Tests to measure the relationship of generated voltage and seepage rate were partly successful. Increased seepage rate produced a small but measurable increase in voltage at the electrodes in stationary positions. The magnitude of the voltage was small in the test flume, being in the order of 10 millivolts for a 35-cubic-foot-per-second-per-day (cfd) seepage rate. At 1 or 2 cfd, the voltage was too small for accuracy of measurement.

Considerable variation of the voltage was measured for seepage when the electrodes were located in one part of the flume and the seepage outflow in another part. Horizontal flow of the seepage in the gravel filter around the outflow manifolds generated a potential not directly related to the seepage through the sand bed.

Dragging the electrodes through the sand bed to measure the potential was notsuccessful. Variations in the voltage, caused by changes in contact resistance of the sand and electrodes, obscured the potential generated by seepage. Suspending the electrodes slightly above the sand bed, a possible configuration for field measurements, produced both positive and negative voltages with time for different seepage rates.

No conclusive results have been obtained from the test flume. Small voltages apparently related to seepage have been measured, but the irregularities in the relationship do not permit prediction of the seepage rate for sand from the voltages recorded. Other soils having lower porosity may generate larger voltages and would, therefore, produce higher and definable voltages.

Hydraulics Branch Report No. Hyd-564, describing 78 electrical logging tests and 58 seepage meter tests conducted on the 75-foot-long outdoor test canal, was prepared.

Scheduled FY67

A report describing tests of electrical logging measurements for seepage detection conducted in the 16-foot-long indoor flume will be completed.

12. Factors Affecting Stability of Artificial and Natural Channels

Scour on the outside and deposition on the inside of curves of trapezoidal earth and earth-lined canals have increased canal maintenance costs. Recommendations have been made to reshape the canals to reduce this scour and deposition. Research studies have been made, including collection of data from field sites and making tests on a hydraulic model in the laboratory to determine the various forces involved as water flows around curves in canals. A trapezoidal laboratory canal 50 feet long, containing a curved section, was used in the testing.

Studies have recently been concentrated on canals built in cohesive earth materials as part of the Lower Cost Canal Lining Program. Field tests have been made on three tractive force test reaches on Farwell Main Canal.

Accomplished FY66

Measurements of boundary shear, velocity distribution, water surface slope, and resistance of canal soils to vane shear tests were made in the Farwell Main Canal in the three tractive force test reaches. A third set of field cross-section surveys were made at 50-foot intervals in the test reaches, and changes in cross sections due to scour and deposition were compared with previous cross sections.

The three notch weirs at the downstream ends of the three tractive force test reaches were calibrated in a hydraulic model for partially submerged and free-flow conditions. Families of discharge curves and discharge tables for each notch weir were developed from the data.

Scheduled FY67

A set of field measurements will be made in Farwell Main Canal using the Preston shear tube and Prandtl tube at maximum discharges to determine hydraulic shear valves, velocity distribution, Manning's N values, and effect of suspended sediment concentration on the erosion of cohesive earth soils. Vane shear values and other soils properties will also be related to erosion of cohesive earth soils.

C. LOWER COST CANAL LINING PROGRAM

Electrical Logging Tests--Cooperation with Engineering Geological Division

Both the Soils Engineering Branch and the Hydraulics Branch have conducted studies at the request of the Engineering Geological Division to help refine the technique of obtaining and interpreting electrical logging charts for locating areas of seepage in canals. Early tests conducted by both Branches with various forms of lead electrodes were inconsistent. Hydraulics Branch tests showed a decay in self-potential (the indicator used to point out seeping areas) when tests were repeated. Soils Engineering tests indicated the possibility of corrosion of the lead electrodes as a cause of decreasing self-potential readings. However, these tests were made using as electrodes the Calomel cells normally used as electrodes in pH meters. These cells are nonpolarizing and seemed to be more consistent in regard to repeatability. Also, the potential readings seemed to be related to the amount of seepage. Because of the success in using Calomel cells in a small test facility, further tests were conducted in the large laboratory dragging flume.

The Hydraulics Branch tests were conducted in a 32- by 4- by 4-foot flume. Perforated plastic drainpipes were spaced at 18-inch centers, transverse to the long axis of the flume. The drainpipes were covered with gravel to provide free inflow into the drains. Eight inches of fine, uniform sand were placed on the gravel bed. Outlet tubes, adjustable in height, were connected to each of the drains. Seepage rates were increased, as desired, from 0 to 35 cfd by lowering the elevation of the outlets of the overflow tubes with respect to the water surface in the flume. During all tests, the depth of water in the flume was maintained nearly constant by means of inlet flow and overflow weirs near the top of the flume. Provision was made for dragging electrodes along the length of the flume using an electric motor speed-reducer drive. With various arrangements of seeping and nonseeping areas in the flume, electrical logs were recorded on charts, using an infinite impedance voltmeter.

Two types of tests were conducted with the nonpolarizing Calomel electrodes: (1) electrodes stationary and separated at fixed distances and (2) electrodes being dragged but separated by fixed distances. Results of the tests for some fixed electrode distances are briefly summarized in Tables 1 through 3. Table 4 gives results of the dragging tests.

Table 1

FIXED ELECTRODE SPACING CENTERED OVER MIDDLE SIX DRAINS
SEEPAGE CHANGE FROM 0 TO 35 CFD

Fixed electrode spacing (feet)	Location of six flowing drains 35 cfd					
	East end		Middle		West end	
	mv reading	time, min	mv reading	time, min	mv reading	time, min
28			1.5	4.3		
			0.5	18.0		
			1.5	50.0		
9	5.5	2.0	8.1	1.5	3.2	2.0
	-	-	3.0	8.2	-	-
	3.7	15.0	4.2	11.4	1.7	13.0
1.5			5.0	1.0		
			2.5	5.0		
			3.5	9.0		

Table 2

ELECTRODES FIXED AT 9-FOOT SPACING
AND USING MIDDLE SIX DRAINS

Seepage rate, cfd	Stable mv reading	Time stable reading was attained after setting seepage rate (min)
35	3.8	11.5
18	3.6	5.0
3	2.8	8.0

Table 3

FIXED ELECTRODES AT 9-FOOT SPACING
CENTERED OVER MIDDLE SIX DRAINS
DRAINS OPENED ONE AT A TIME AND SET AT 35 CFD

Number drains opened	Reading 15 minutes after opening of mv
1	1.2
2	2.2
3	3.0
4	4.2
5	4.7
6	5.2

Table 4

ELECTRODES DRAGGED AT 9-, 4-, and 1-FOOT SPACINGS
35-CFD SEEPAGE, MIDDLE SIX DRAINS

Traveling electrode	Difference in mv between no-seepage and seepage runs		
spacing, feet	Electrodes at east end of flume	Electrodes at middle of flume	Electrodes at west end of flume
9	4	0	7
4	2	0	2
1	0	2	0

Table 1 presents time voltage readings and log histories for three fixed-electrode spacings with a seepage change from 0 to 35 cfd using the middle six drains. The centerline between electrodes coincided with the midlength of the bed seepage area. For the 9-foot spacing, the electrodes were left in the center of the flume. Seepage changes from 0 to 35 cfd were set in the six east end drains and then in the six west end drains.

Table 2 shows the effect of varying the amount of seepage. Column 1 shows the seepage rate for the middle six drains. Column 2 shows the reading in millivolts with a fixed 9-foot electrode spacing centered over the seepage area, after the seepage rate became stabilized. Column 3 shows the elapsed time between setting the seepage rate and reading the millivolt meter.

Table 3 shows the effects of varying the seepage area for a fixed 9-foot electrode spacing centered over the six middle drains. Starting at one end, drains were successively opened to pass 35 cfd, one each 15 minutes. Column 1 shows the number of drains opened and Column 2 shows the mv reading after about 15 minutes.

Table 4 shows the results of dragging tests with electrodes at three different spacings and with 35-cfd seepage set in the middle six drains. Control runs were obtained for no seepage for each electrode spacing. Column 1 shows the electrode spacing. Columns 2, 3, and 4 show the differences in mv readings between the control and seepage runs when the electrodes were at the east, middle, and west ends of the dragging flume, respectively.

Summarized tests in Tables 1 through 4 to measure the relationship of generated voltage and seepage rate were partly successful. As shown in Table 2, an increased seepage rate produced a small but measurable increase in voltage at the electrodes in stationary positions. The measured voltages were small in the test flume, being from 2 to 10 millivolts for a seepage as large as 35-cfd seepages. The time lag between a seepage change and its associated voltage reading shown in Tables 1 through 3 suggests possible difficulty in interpreting logging charts when electrodes are dragged.

As shown in Table 1, voltages were measured for seepage when the electrodes were located in one part of the flume and the seepage outflow in another part. Horizontal flow of the seepage in the gravel filter around the outflow manifolds generated a potential not directly related to the seepage through the sand bed.

In future tests, isolating the seeping portion of the bed by means of impervious barriers may eliminate horizontal flow through the gravel drain bed.

The use of clay-silt soils in the seepage bed may produce larger logging voltages and possibly give, in greater definition in measuring, smaller seepage rates.

A report covering these results in more detail is being prepared.

Erosion and Tractive Force Studies

During August 1965, measurements of boundary shear velocity distribution, water surface slope, and soil vane shear tests were made on the three established test reaches on Farwell Main Canal, Nebraska. Suspended sediment samples and bed material samples were also obtained. To maintain a continuous record of water surface elevation and discharge through each of the test reaches, six water-stage recorders were used upstream and downstream from the three-notch weirs at the ends of each of the test reaches. Maximum sustained discharge during the 1965 irrigation season reached only about one-half of the canal design capacity; and consequently, the maximum tractive forces during these flows were somewhat less than maximum tractive forces expected when the flow reaches full design discharge. Cross sections taken at 50-foot intervals at the end of the irrigation season showed that there was no significant change in bed elevation, indicating no change in disposition or scour. A computer program and the X-Y plotter were utilized to quickly plot cross sections for comparison with cross sections taken in previous years.

Hydraulic model calibrations were partially completed in the Hydraulics Branch Laboratory for the three notched weirs so that a continuous record of discharge through each test reach could be made.

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Cross section measurements will be made to determine if there has been scour and/or deposition in the test reaches during the 1966 irrigation season. The hydraulic data obtained to date were analyzed. Based on the results of this analysis, it was decided that hydraulic field measurements will be required during FY67. Recording of water surface elevation and periodic cross sectioning and possibly soil sampling, in each of the three test reaches, will need to be continued by field forces during FY67. Calibrations of the three notched weirs in the Hydraulics Branch Laboratory will be completed for both free-flow and submerged conditions, and a report will be prepared.

D. FY1968 NARRATIVE JUSTIFICATION

WATER RESOURCES ENGINEERING RESEARCH

HYDRAULICS (Including Flow in Aquifers, Sedimentation, Water Measurement)

Location--Office of Chief Engineer, Denver, Colorado

Description--Hydraulic research is conducted to meet requirements for advanced information on hydraulic structures, reservoirs, conveyances, and equipment, flow measurement, flow in aquifers, drainage, seepage, and sediment control. Such studies are carried on in the laboratories and at completed Bureau structures to obtain data that will improve planning, designing, and operating hydraulic works and systems, develop analytical relations, correlate design criteria with observed performance, and reduce initial construction and maintenance costs. Studies are also made to apply advanced concepts and observed hydraulic behavior to design practice for hydraulic structures, reservoirs, conveyances, and machinery.

Hydraulic research is also performed to develop new improved relations for correlating experience and technical concepts with resultant improved designs. Such relations may be associated with measurement techniques, data interpretation, performance of hydraulic equipment, or structural shapes for hydraulic flow improvement. Research items cover investigations in both closed conduit and open channel flow for periods of transient as well as steady state conditions.

The research program is divided into three general categories, each of which includes several specific objectives:

1. General research.--Obtain additional data to extend capability to design energy dissipators that convert flows from high to low velocity to prevent flow channel erosion and structural damage to dams, canals, and rivers; evaluate hydraulic phenomena such as cavitation, vibration, pressure distribution, velocity distribution, air demand, and friction losses introduced by physical characteristics of flow surfaces and configurations of conduits and hydraulic equipment, including gates, valves, bifurcations, sudden enlargements, and flow surface irregularities; study hydraulic transient phenomena; develop design criteria for open channels, including channel stability and estuarine behavior; establish seepage loss measurement methods and equations; investigate draft tube surges in turbines and governor systems, pump and turbine capacity, and testing procedures, speed and settings for turbines and pumps, suction tubes for large pumps; advance the knowledge of stratified flow in reservoirs and conveyances; and develop and improve laboratory techniques, instrumentation, and test equipment. The program also includes studies of high-velocity flow in chutes and head losses at structures and transitions.

2. Aquifers, drainage, seepage, and sedimentation research.--Extend knowledge of the flow of ground water in aquifers, ground-water recharge, factors affecting the design of drains, and the flow of seepage from canals; and determine the effect of boundary shear on critical resistance to erosion of soil so as to extend the knowledge of basic factors affecting the design of unlined and earthlined canals.

3. Water measurement.--Study water measurement devices for evaluating existing designs, develop new water measurement methods and devices, and study methods of improving water accountability. Continue the investigation of using tracer methods of measuring discharges in high-head turbines and pumps.

Status of Work as of June 30, 1966--Work accomplished on these subjects in FY66 was as follows:

1. General research.--

a. Energy dissipators.--Extensive studies were made to determine reasons for debris moving into and severely damaging a specific hollow-jet valve stilling basin, and the required modifications for satisfactory operation were determined. Studies were made on an unusually narrow and deep stilling basin for high slide gates. A vertical stilling well facility was placed in operation and exploratory tests performed. Studies and data analysis were continued on the Type VI basin and on a sudden enlargement energy dissipator downstream from an 8-inch butterfly valve. Piezometers and accelerometers were installed in the center dividing wall of the Yellowtail Dam hollow-jet valve stilling basin, and dynamic pressure and vibration measurements were obtained for a wide range of discharges. Provisions were made for pressure transducers in Crystal Dam outlet works stilling basin.

b. Gates, valves, and orifices.--A computer program was written to aid in determining the air vent size for a gate chamber in which the water surface was dropping. A configuration for walls downstream from a slide gate was determined which was essentially free from subatmospheric pressures. Discharge coefficients were obtained for various size orifices in circular planes. Equipment was acquired and construction begun on a facility for testing prototype gate seals at heads up to 600 feet.

c. Pipeline and tunnel hydraulics.--A report was issued on the design of check towers and air vents for installation in a 124-mile-long pipeline. The laboratory installation to investigate the dynamics and hydrostatic forces during surging in the pipeline was revised, and studies were continued. The results of the studies in the surge model were used to develop a generalized ADP program for application to a large variety of pipeline surge problems. Pressure fluctuations were measured in concrete pipe laterals of the South Gila Valley Unit, Yuma, Arizona. Tests of the Salt Lake City Aqueduct were started to determine the capacity and measure resistance coefficients of long concrete pipelines.

d. Instrumentation.--Studies were intensified on data acquiring and reducing systems. Both the quantity and quality of information from laboratory and field studies were improved by new instrumentations resulting from these studies. Use of computer techniques and applications was increased in analyzing data from laboratory and field studies. Both digital and analog methods were applied extensively to provide greater amounts of information in a shorter time.

e. Flow surface protection.--Initial studies were made with an open channel model to determine the effect of entrained air in preventing or reducing cavitation damage to irregular surfaces subjected to high-velocity flow. The inconclusive results were analyzed to aid in designing a new test apparatus to further define the possibilities of using entrained air as a protective media.

f. Open channel hydraulics.--An analytical study of a flow junction was compared with a model study, and a report on the study was issued. A method for determining losses through similar junctions was outlined. Studies were conducted and reported on two canal sections to determine the characteristics of rejection surges. A report was published on the results of correlating surface resistance coefficients measured by point gage and by velocity distribution methods. Measurement of weed growth effect on channel capacity was made in the Carter Lake weed test facility.

g. Intakes, entrances, and transitions.--An intensive review of the literature on several disciplines concerned with basic flow properties of draft tubes was conducted, and a model of a turbine scrollcase and conical draft tube was constructed and tests started to correlate empirical results with the theory. An analysis was made of a current penstock entrance and a proposed smaller entrance to compare hydraulic properties and cost. Planning was started on a model study of the proposed entrance to accurately define its hydraulic properties. Reports were issued on the results of studies on a sloping intake and on high-capacity sluices.

h. Quality of water as affected by stratified flow.--A comprehensive bibliography of research in stratified flow was prepared, and a progress report defining the present state of research and proposals for additional research was prepared. Construction of a laboratory facility for study of temperature-induced stratification was started.

2. Aquifers, drainage, seepage, and sedimentation research.--Measurements were made with a Preston shear tube and a Prandtl pitot tube to determine boundary shear distribution and velocity distribution values on a 60° angle curve in the 50-foot-long trapezoidal laboratory canal.

Measurements of boundary shear, velocity distribution, water surface slope,and resistance of canal soils to vane shear tests were made in the Farwell Main Canal in three tractive force test reaches at lower than design discharges. A Preston tube was used to measure boundary shear in an unlined field canal for the first known time. Secondary equipment such as the electronic writing recorder, manometer system, and a pressure transducer were used with the Preston tube for measuring and recording boundary shear. Cross sections were taken at 50-foot intervals in the three tractive force test reaches, and the change in cross section due to scour and deposition determined by using a computer program and the X-Y plotter. Water surfaces upstream and downstream from the three notch weirs at the ends of the three test reaches were recorded continuously to obtain a continuous discharge record. Model tests were conducted in the laboratory on the three different notch weirs built in Farwell Main Canal, and calibration tables and curves were obtained.

A series of tests were completed in the 4-1/4-foot-deep by 2-1/2-foot-wide by 16-foot-long ground-water model to show patterns of flow in a 2-part aquifer drained by a pumped well. An electronic conductivity cell and recorder were used to continuously measure salt concentration in the well drain effluent.

3. Water measurement.--Reports were published on studies of a variable area punched-tape waterflow meter and a pipeline propeller-type meter. Accuracy of discharge measurement and operating characteristics were investigated for both meter types. A draft report was completed on the results of the study of flat-bottomed trapezoidal flumes. A report draft on the magnetic flowmeter investigation results was completed.

Studies of the dispersion of tracer materials in flowing water for discharge measurement were continued in the Hydraulics Branch and at Colorado State University. Dispersions coefficients from 8-inch and 36-inch pipe test facilities will be compared as a result of the studies. Data obtained will be extrapolated to a prototype turbine penstock for field discharge measurements with radioisotopes later in the calendar year.

Instructional and consultational material was assembled for design groups and the Irrigation Operators' Workshop from laboratory investigations, field studies, and from technical literature on water measurement devices. The material was used to answer questions on measurement devices and to help raise the quality of irrigation water measurement.

Construction of a facility was started for study of a propeller-type open flowmeter study. Difficulty has been encountered in the field in making accurate discharge measurements for a particular turnout geometry. The study will attempt to find the causes of the inaccuracy.

FY67--

1. General research.--Investigations will continue to emphasize development of energy dissipators, principally a modified hollow-jet valve stilling basin and vertical stilling wells. Reports will be issued on a narrow, deep slide gate basin and on a modification to a hollow-jet valve basin. Studies will continue on sudden enlargement energy dissipators downstream from gates and valves and on the Type VI basin. A model vortex-type stilling basin will be put in operation. Dynamic pressure and vibration measurements on prototype structures will continue as opportunities arise. Investigations of various conical draft tubes will be conducted and surge suppression configurations will be tested in the model draft tube. Studies of vortex formation in shallow submerged inlets in reduced pressure environments will be initiated. A model will be built and studies started on the reduced size penstock entrance. The research facility for the temperature-induced stratified flow study will be completed and a testing program initiated. A continuing search will be made to amplify the bibliography on stratified flow research, and a progress report will be published. Studies on surface alinement and irregularity tolerances for high-velocity flow, including the effects of entrained air, will be advanced. Research on air demand at regulating gates in model and prototype, evaluation of gate seal materials, and orifice-controlled regulators will continue. Surges in pipelines, draft tubes, and canals, and initial studies on size and thickness of riprap protection will also be a part of the program.

2. Aquifers, drainage, seepage, and sediment research.--The stability of unlined canals in cohesive earth materials as affected by erosion and deposition caused by flowing water will continue to be studied in field canals. Research using analog and hydraulic models will be performed to determine fluid mechanics of drainage from sloping agricultural lands, displacement of saline waters from single- and two-part aquifers, and tile drain efficiency related to joints and envelope materials. Emphasis will be made on the study of transmissibility of ground-water aquifers in a variety of situations.

3. Water measurement research.--Studies will be conducted to evaluate water measuring devices for practical use in open channel and pipeline distribution systems used to distribute irrigation water. Both commercial and Bureau-developed devices that can be used in pump and turbine pipelines will be evaluated. Preparing reports as a part of the research will provide an outlet for the information and a source of instructional material for use in advising operators on proper distribution and measurement of irrigation water. The study of acoustic, thermodynamic, tracer, and pressure-momentum methods will help improve the measurement of flows from pumping plants and powerplants. Work will continue in cooperation with the Atomic Energy Commission on the use of radioactive materials for high-head turbine and pump discharge measurements.

FY68--The following projects will be active:

1. General research.--

a. Energy dissipators.--Development of turbine-type, plunge-type, and sudden-enlargement-type energy dissipators will be continued in the laboratory. Prototype energy dissipators will be given hydraulic performance tests and compared with laboratory studies whenever possible.

b. Gates, valves, and orifices.--Analytical, model, and prototype studies of the air demand phenomena will continue. The effect of a vertical curve in the conduit upstream from a slide gate will be investigated. The orifice studies will be completed and a report combining the results will be published. Tests on Teflon-clad gate seals in an improved test facility will be initiated.

c. Pipeline and tunnel hydraulics.--Measurement of head loss in tunnels and pipelines will be continued to determine the resistance coefficients of new and aged concrete surfaces. Studies will be started to determine the force on submerged pipelines caused by tidal variations, wave action, and shifting currents. Transient flow conditions in long pipelines such as Canadian River Aqueduct will be measured.

d. Instrumentation, data acquisition, and computer techniques.--Objectives of this research are to improve the quality, increase the quantity, and reduce the time for analysis of data measured in laboratory and field studies. Continual investigation of new equipment, instrumentation, and techniques will provide means of accomplishing the objectives.

e. Flow surface protection.--Studies will continue to define specific design problems and determine beneficial effects of entrained air in preventing cavitation damage and the need for surfaces resistant to cavitation damage. A summary of field and laboratory investigations will be made into a progress report. Designs will be made for a research facility to provide a high-velocity jet of high temperature, corrosive fluids to determine resistance of metals and alloys.

f. Open channel hydraulics.--A report on the characteristics of rejection surges will be prepared. Studies to determine relationships between size of uniform and of graded riprap and the flows under a gate will be made.

g. Intakes, entrances, and transitions.--Whenever possible, prototype investigations will be made on conduit entrances, transitions, and changes in alinement. A report on a modified pressure conduit entrance will be prepared.

h. Quality of water as affected by stratified flow.--Laboratory studies on stratified flow will be expanded to include chemical stratification, selective withdrawal, and estuarine hydraulics. Stratification in prototype structures will be studied and compared with the model investigations.

2. Aquifer, drainage, seepage, and sedimentation research.--Analytical studies, hydraulic and analog model research will be made on the fluid mechanics of drainage from sloping agricultural lands and tile drain efficiency of joints and envelope materials. Mathematical, hydraulic, and analog model studies will be aimed at the mechanics of displacement of saline waters from homogeneous, nonhomogeneous, and stratified aquifers and studies of basin groundwater storage.

3. Water measurement.--Investigation of tracer methods of discharge measurement, with emphasis on radioactive materials, will continue for open channel and closed conduit flow systems. Searching for new and better means of measurement and evaluating devices will be a major part of the research program. Increased costs for water and reduction in resources will probably require increased use of underground distribution systems. Devices compatible with automatic control and measurement of water from closed conduit systems will be studied to help solve irrigation water delivery problems.

Justification--Bureau of Reclamation water resources engineering activities clearly indicate an urgent need for a variety of general hydraulic research studies to provide comprehensive knowledge for specific design problems, and generalized data needed in developing better operating, longer lived, and more economical hydraulic systems, structures, and equipment.

New concepts in energy dissipation devices must be explored and developed to supplement concepts presently undergoing evolutionary changes and refinements. Improved gates, valves, and other control devices are needed to achieve utmost reliability, service life, and economy. Much additional work is needed to ascertain type and amount of damage that can occur on surfaces subjected to high-velocity flows, and to develop economical and practical remedial measures.

Transient flow such as surging in canals and pipelines continues to need examination so that costly operating difficulties can be identified and avoided during design stages. Hydraulic problems associated with power and pumping plants are particularly vexing, and demand much attention if preventive and/or corrective measures are to be developed.

Flow behavior in reservoirs and conveyances has great bearing upon water quality and temperature and, hence, upon agriculture and marine life. Thus, there is urgent need for knowledge of primary factors involved in the behavior of this type of flow.

Improvement in measuring equipment, measuring techniques, and data analysis continues to be mandatory for most efficient use of manpower and plant facilities in the research effort.

Research in aquifers, seepage, drainage, and sedimentation will provide answers required to develop improved and less costly structures and conveyance systems. Continued research will enable a reduction in the cost of sediment removal from canals and other conveyance structures, reduction in the cost of earth canals, better bank protection and channelization in rivers, and improved procedures for designing conveyance devices and structures. Research in the closely related fields of waterflow in aquifers and seepage problems will lead to better understanding of complex problems connected with the design of agricultural drains, wells, works for the replenishment of underground water, and other related facilities.

The growing national requirement that water be conserved as a natural resource makes it necessary to account for available water and then to determine where and how it is being used. Accurate water measurements are vital to the accounting process, and are often difficult to make. Special equipment and procedures are, therefore, needed. In the program, Use of Water on Federal Reclamation Projects, the measurement of irrigation water in open channels, canals, ditches, and pipelines is one of the most important parts. In other Bureau work, reliable measurements are required to insure equitable distribution of water to users taking their supply from a common source, and to determine the total quantity diverted.

Accurate seepage and/or waterflow measurements are required to determine losses in conveyance systems. The monetary value of lost water is used to determine the economic feasibility of providing repairs or waterproof lining for earth canals and to help determine the sizes of canals needed on future projects.

New water measurement devices are continually being developed and promoted, and older devices are being modified, adapted, and improved for better measurement practices. In the role of technical expert and adviser, the Bureau is obliged to keep abreast of these developments by making extensive evaluations of water measurement devices and procedures, in the laboratory and in the field. Upgrading of existing water measurement devices and establishing new devices in areas where water has never before been accurately measured will help to account for water now being used, and in many cases will result in reducing waste and making water available for more users at a lower unit cost.

The research activities which have been conducted the past few years and those planned for FY67 and FY68 are closely associated with planning and design problems. These activities indicate high promise for monetary savings in this area, and promise a maximum of useful results with a minimum expenditure of funds.

LEGEND: Type of Activity

Preconstruction and Other Work — Construction

LINE NO.	CLASS AND ACCOUNT	PROGRAM ITEM	QUANTITY	UNIT	ESTIMATED TOTAL	TOTAL TO JUNE 30, 66	FISCAL YEARS 1967	1968	1969	1970	1971	1972	1973	BALANCE TO COMPLETE	ESTIMATED COMPLETION DATE	LINE NO.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1		PLAN FORMULATION INVESTIGATIONS														1
2		Special Studies														2
3	16-0-799	Power Intertie Studies (D)			136,887	135,748	1,139									3
4																4
5		TOTAL--Plan Formulation Investigations														5
6					136,887	135,748	1,139									6
7																7
8		GENERAL ENGINEERING AND RESEARCH														8
9	18-0-801	Atmospheric Water Resources Research (D)			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		9
10																10
11																11
12	[illegible]	Water Resources Engineering Research (D)														12
13	1	Aquatic Weed Control			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	342,711		13
14	2	Chemistry and Physics Technology in Materials and Methods			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	345,395		14
15	3	Concrete			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	737,033		15
16	4	Electric Power			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,105,273		16
17	5	Evaporation Reduction			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		17
18	6	Hydraulics			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		18
19	7	Lower Cost Canal Lining			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	895,574		19
20	8	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		20
21	9	[illegible] Engineering			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		21
22	10	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		22
23	11	Water Quality and Pollution Control			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		23
24																24
25																25
26		TOTAL--Water Resources Engineering Research			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		26
27																27
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NOTES: [illegible] Office of Chief Engineer

Acting Chief Engineer

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

E. [illegible] CONTROL SCHEDULE

JUL 28 1966

E. COMMENTARY ON SIGNIFICANT DEVELOPMENTS IN HYDRAULIC RESEARCH PROGRAM DURING THE FISCAL YEAR 1967

1. Prototype Hydraulic Tests
2. Water Measurement Program
3. Dispersion Studies
4. Turbine and Pump Discharge Measurements with Radioisotopes
5. Turbine Discharge Measurements, Flaming Gorge Dam Powerplant
6. Capacity Tests, Salt Lake City Aqueduct
7. Pressure Fluctuation Measurements, Gila Project
8. Friction Factors for Large Conduits
9. Canal Capacity Studies
10. Electrical Logging Tests
11. Prototype Stilling Basin Test Facilities
12. Scour Tests, Farwell Main Canal
13. Flow Resistance Tests at Carter Lake Test Station
14. Curved Channel Study
15. Gate Seal Tests
16. Draft Tube Surge Studies
17. Design and Research on Stilling Basins
18. Stilling Basins for High-head Outlet Works with Slide Gate Control
19. Modification to the Design of Hollow-jet Valve Stilling Basin
20. The Role of Hydraulic Research in Water Quality Studies

Prototype Hydraulic Tests

Eight pressure transducers, six accelerometers, and related electrical circuits were installed in the center wall of the Yellowtail Dam outlet works stilling basin. The instruments were installed to measure individual and differential dynamic pressures acting on the wall and the resulting movement of the wall. Three sets of measurements were made, one with a 500-cfs release through one side of the basin, then with symmetrical discharges of 1,000 cfs through each side of the basin (total flow of 2,000 cfs) and again with a total symmetrical flow of 3,100 cfs. The magnitudes of the measured pressures were moderate and no movement or vibration of the wall was indicated by the accelerometers. Head losses and pressures were measured in an 8-foot-diameter outlet pipe and the center conduit of the tunnel plug outlet works in Glen Canyon Dam. The measurements in the outlet pipe revealed that the relatively low reservoir head available at the time of the measurements was not sufficient to maintain positive pressures in a portion of the pipe and cavitation action resulted at a vertical bend in the pipe. These measurements also provided head loss data for large circular bellmouth entrances. The test of the tunnel plug conduit provided head loss and pressure distribution data for large rectangular conduit entrances and pressure distributions on flow surfaces downstream of high head slide gates. The left diversion tunnel was unwatered to inspect the concrete lining following releases up to 29,600 second-feet. Although 2,800,000 acre-feet of water passed through the tunnel at flow velocities ranging from 100 to 150 feet per second, no significant additional damage to the concrete lining was detected. A 7-day test at the end of the period with a hydraulic jump in the area of maximum tunnel damage showed that additional exposed reinforcing bars were torn loose, but no apparent erosion of the concrete lining resulted from the hydraulic jump, indicating the concept of the original design to be correct in principle. Three tests of pressure fluctuations in unreinforced cast-in-place concrete pipe on the South Gila Valley Unit of the Gila Project were performed to determine whether the fluctuations were a possible cause of pipe cracks. The test measurements revealed that the maximum operational pressures were within design values. Test facilities were incorporated into the design of the following prototype structures: (1) Sugarloaf and Crystal Dams outlet works stilling basins for measurement of hydrodynamic forces acting on the structures and for measurement of any structural reaction; (2) outlet works control gates of Ruedi Dam and Morrow Point Dam for measurement of pressures in the vicinity of gate leaf slots developed during recent model studies; (3) two free-flow tunnels each on the San Juan-Chama and Fryingpan-Arkansas Projects for determination of hydraulic friction coefficients of concrete tunnel lining; (4) inverted siphons of the Tehama-Colusa Canal for measurement of inlet and outlet transition head losses.

Water Measurement Program

Because of the continually increasing need for better utilization and conservation of water resources, a program was formulated to refine, standardize, and simplify the design of water measurement devices. As part of this program, laboratory studies were conducted on a new tapered-tube, variable-area-type flowmeter that records discharges on paper tape (Figure 11). This flowmeter was developed to provide records of irrigation water delivery on punched tape for automatic accounting and billing of water users. The flowmeter was calibrated and head losses were determined to aid designers in applying this device to irrigation distribution systems. The studies indicated that the flowmeter is accurate and consistent; however, the meter head losses are considered high compared to losses for other meters of similar capacity. A commercial 4-inch magnetic flowmeter was evaluated by hydraulic study. The accuracy of discharge measurement was checked and found to be within the specifications of the manufacturer. The ease of use of the meter, flow recording equipment, and flow totalizing register was investigated for application to irrigation water distribution. Results of a laboratory study of a 2-foot vertically adjustable weir were published in a formal report. This water measuring device has a movable Cipolletti weir plate that bears against a stationary weir plate and can be adjusted vertically by means of a threaded screw and handwheel. Besides serving as a measuring device, the adjustable weir permits checking or controlling flow in irrigation turnouts. The studies developed a means of standardizing the

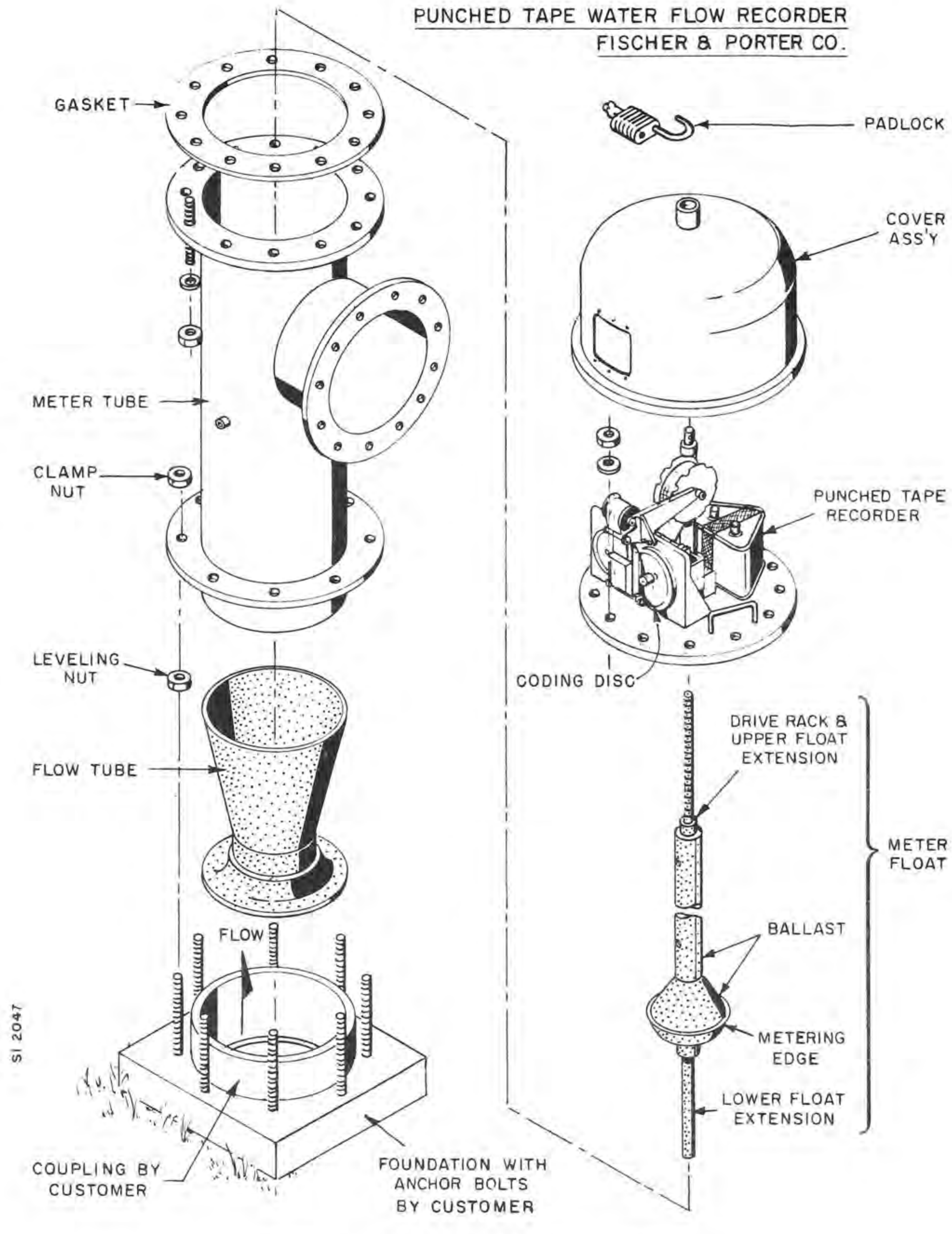

Figure 11. Punched tape waterflow recorder.

method of relating elevation of the movable Cipolletti weir crest to the head of water on the stationary weir crest. The studies also indicated that reliable discharge measurements could not be made for movable crest elevations less than about 1/10 foot above the stationary crest. The Hydraulics Branch participated in the Irrigation Operators' Workshop by collecting, writing, and presenting information current from laboratory and field studies, and technical literature on water measurement devices to operators from irrigation projects. Formal teaching sessions were conducted both at the 5th Annual Denver Workshop and at the 1st Annual Utah State University Workshop by members of the Hydraulics Branch staff. A comprehensive discussion on Parshall flumes has been prepared to be included in the workshop sessions for next fiscal year. The Hydraulics Branch is conducting hydraulic investigations in an AEC-USBR joint program to develop improved methods for measuring discharge through high head turbines and pumps using radioisotope methods. An 85-foot-long section of 8-inch-diameter pipe is being used in the laboratory to study tracer dispersion in a pipeline. Dye and salt tracer solutions can be injected into the pipe at various points along its length and the tracer concentration in the pipe flow measured at a downstream station. To obtain an accurate measurement of discharge, the tracer must be uniformly dispersed (completely mixed) across the pipe cross section at the sampling station. The studies have concentrated on determining the minimum distance downstream from the tracer injection station for which the mixing is complete, and attempts to reduce this distance by various means of injection. Similar studies on an 800-foot long 36-inch pipeline facility are being performed at Colorado State University under contract. Preparations are underway to perform discharge measurements using radioisotope tracers on a prototype turbine facility at Flaming Gorge Dam.

Dispersion Studies

A digital computer program was written for the purpose of analyzing salt velocity conductance records obtained from previous laboratory and field studies. The purpose of the program and analysis is to determine the mean concentration of the salt solution and dilution with the pipe flow, the normality of the longitudinal diffusion, and the extent of dispersion at two electrode stations. The results of this analysis are expected to relate the Venturi measured pipe flow and that computed by the standard salt-velocity method, to that computed by the total count method using the salt solution as the tracer. The results are also expected to indicate the degree of lateral dispersion of the salt solution at the cross section containing the electrodes. Studies of the dispersion of the salt and dye solutions are proceeding in the 8-inch pipeline. Salt and dye were simultaneously introduced into the pipe flow from two 1/8-inch-diameter holes. The injectors were located at opposite ends of the horizontal and then the vertical diameter of the 8-inch pipe. The injection station was located 78 diameters downstream from the pump and 55 diameters upstream from the sampling station. Use of two 1/4-inch injectors on either the horizontal or the vertical axis produced a reasonably uniform concentration profile on the same axis as the injector. Results from the analysis of data from both the conductivity and dye dispersion measurements indicate that 95 to 97 percent lateral mixing had occurred in a pipe length of 55 diameters. Future measurements are planned for relocating the injection probes at selected incremental distances upstream from the conductivity and dye sampling station. From these measurements, it is expected to obtain a correlation between the degree of mixing and the mixing length. Assembly of the nuclear counting device has been underway. Testing with radioisotopes will commence after the preliminary dispersion methods for the salt and dye have been more firmly established.

Turbine and Pump Discharge Measurements with Radioisotopes

A contract with Colorado State University, Fort Collins, Colorado, for research and development of the use of radioisotopes in making accurate discharge measurements in pipelines was signed and dated July 31, 1965. Work on this contract was not started until the month of September and studies were begun in a 36-inch pipe, located at the Fluid Dynamics Laboratory on the Foothills Campus. The purpose of this study was to determine the effectiveness of natural turbulence of a developed velocity distribution to produce a uniform cross-sectional diffusion of a tracer introduced at some upstream cross section. Work on this contract proceeded with outdoor measurements until the month of December, when inclement weather forced the investigators inside. During this period, Pontacyl Pink B dye was used as a tracer in the pipe flow and a Turner fluorometer was used to determine the dye concentration.

A contract amendment was written during the months of December and January to extend the scope of the work described by the contract. This amendment was written for signing by January 31, 1966, and is in the process of execution.

Turbine Discharge Measurements, Flaming Gorge Dam Powerplant

Plans were made for measuring the flow of water through the turbine with radioisotopes, during the turbine acceptance tests planned for January 24, 1966. Although all of the studies necessary to define mixing characteristics, injection means, and the method of sampling have not been completed in either laboratory or field studies, the discharge measurements were planned to coincide with the turbine acceptance tests. A direct comparison could thus be made during these tests with the Gibson method of discharge measurement. Injection and sampling equipment were prepared and calibrated for these measurements to inject radioisotopes into the flow near the upstream end of the penstock and to sample near the entrance of the turbine. A high-head injection pump (9,000 millimeters per hour at 5,000 psi) was purchased for injecting the isotopes. The sample tank method was planned for use in determining the concentration of the radioisotopes after mixing with the flow. These radioisotope discharge measurements could not be made during the acceptance tests because permission was not received from the State of Utah for the use of the radioactivity. These discharge measurements may still be performed, providing permission is received from the health authorities in Utah.

Capacity Tests, Salt Lake City Aqueduct

At the request of the Regional Director's office, Salt Lake City, and the Denver Office Canals Branch, a capacity test was planned for the Salt Lake Aqueduct. The aqueduct is about 47 miles long and consists of a series of concrete pipe sections, tunnels, and inverted siphons. There had been some indication that the total flow through the aqueduct would exceed the design value, and a series of measurements were requested to establish the amount. Preparations for measurements of discharge and head through various features of this aqueduct were completed. Because of drought conditions, and the high demand for domestic water, these tests could not be performed during the fall. They are planned for the summer of 1966, provided sufficient water is available.

Pressure Fluctuation Measurements, Gila Project

Pressure fluctuations were measured in December 1965 and January 1966 in two reaches of Lateral 6.5 in the South Gila Unit. This lateral was designed to utilize cast-in-place concrete pipe that has shown a tendency to crack circumferentially and longitudinally. The purpose of these measurements was to determine if pressure fluctuations, caused by operating procedures, were a possible cause of the cracking. Measurements of surge were made in the lateral for rapid closures of turnout delivery valves that had been discharging up to 133 percent of design flow. Pressure transducers were placed directly in the water in the pipe connected to piezometers, and to the turnout valves. They were used to record the rate and magnitude of the surge. The pressure measuring equipment was located at the entrance, near the middle and at the end of the two pipe sections, and at the valve. Good records of the fluctuations were obtained in both test series and the pressures were apparently within design values.

Friction Factors for Large Conduits

The previous supply of Engineering Monograph No. 7, published in the Denver Office, had been expended and the Technical and Foreign Services Branch had made arrangements, through the Superintendent of Documents, Washington, for a printing. The galley proof of the monograph was reviewed in October 1965. Copies of this monograph were received in January 1966, although they were apparently printed under the date of September 1965.

Canal Capacity Studies

Information was received from the Columbia Basin Project, Ephrata, Washington, that the head loss measurements in the Main and Potholes Canals were not progressing as well as had been anticipated at the beginning of the year. This difficulty was encountered because the weeds and algae were not growing as rapidly as in past years. Tests had been planned to provide information on the effects of biological growths on increased resistance to flow. Water temperatures during the year had been lower than in previous years, reducing the rate of growth and thus prevented obtaining a test series which would include chemical treatment of the growth and loss measurements immediately thereafter. Data acquired in the forepart of the year was to be analyzed and transmitted to the Denver Office.

Assistance was given to personnel in the Division of Irrigation, Regional Director's office, Sacramento, California, in the design of gages for the measurement of water surface elevation. This office, in past years, has used gages designed by the Denver Office and has found that under severe field conditions, the gages become damaged. The office proposed to increase the strength and modify the gages to allow a measurement without removing the gage from the water. A drawing of this gage was sent to Denver for review. A review showed that the gage would apparently accomplish the desired measurements and only a few suggestions were made for improvement.

Capacity studies of the Delta-Mendota Canal began in 1957. A comprehensive program of sampling the biological growths in the Delta-Mendota Canal has been in progress since 1960, and two of the growths under consideration are fresh water sponges and clams. Regional personnel concerned with these studies would like to know the effect of the growth of sponges, in patches to 6 feet in diameter, on the surface resistance to canal flow. They would also like an evaluation of the resistance offered to flow by clam shells that are cupped upward or downward. Discussions were held with regional personnel on the possibilities of representing the sponges and clams in the laboratory and measuring their resistance effect on air or waterflow. To accomplish these tests, the region would send, to Denver, samples of these growths.

Electrical Logging Tests

The Division of Engineering Geology has been given assistance in the electrical logging program by the Soils Engineering and Hydraulics Branches. The Soils Engineering Branch has attempted to measure the self-potential generated by water flowing through 8-inch-diameter permeability samples. The seepage flow through these samples has produced rather large changes in self-potential, but many inconsistencies were found in the relationship of the potential and the flow rate. Improvement in apparatus, to include nonpolarizing electrodes, appeared to give better results than when using lead electrodes.

Studies of a similar nature have been carried on in the Hydraulics Branch in a 4-foot by 4-foot by 32-foot-long seepage flume (Figure 12). Provisions had been made to withdraw, at a uniform rate, water through a sand and gravel filter in the bottom of this flume. Both moving- and fixed-electrode studies using lead were completed in this test facility and the studies resulted in inconsistent measurements of potential. Because of the differences encountered in the Soils Engineering Branch in using lead electrodes, the Division of Engineering Geology asked that the nonpolarizing electrodes be used in the larger flume. These tests have not been performed to the present, but will be included in future measurements.

Prototype Stilling Basin Test Facilities

Facilities for installation of test instruments in Sugar Loaf and Crystal Dams stilling basins were included in the construction specifications. Postconstruction installation of pressure transducers and accelerometers will permit hydrodynamic and structural response measurements in these stilling basins at locations where major fluctuations of pressure have been measured in models. Plans are being made for recording information from these instruments on magnetic tape.

Scour Tests, Farwell Main Canal

The Hydraulics Branch made shear measurements in three test reaches during the period of maximum canal discharge for the 1965 irrigation season. The reaches were designed and constructed with hydraulic slopes that would result in deposit of sediment in one reach, stable conditions in the second reach, and scour in the third reach. To determine the hydraulic conditions actually occurring in these three reaches, boundary shear measurements were made using a Preston shear tube designed and constructed in the Hydraulics Branch Laboratory and electronic recording equipment to convert the data to shear values. Readings were taken at selected stations across the chosen canal section. A Prandtl tube was also used with the recording equipment to measure and record velocity distributions in the test section. Hydraulic slope measurements were made, soil vane shear tests shown in Figure 13 were conducted, and suspended sediment and bed sediment samples were taken to determine their relationship to the stability or nonstability of the test reaches. Cross section measurements were made at the end of the irrigation season to determine the amount of scour or deposition that occurred as a result of passing a given quantity of water through the reaches.

Normal depth at the downstream end of each of the test reaches is maintained by Cipolletti weirs which are used to measure the flow also. The weir inverts are at the upstream canal bottom elevation and there is a small drop in elevation below the weirs. Therefore, they operate much of the time in a partially submerged condition requiring the discharge calibration to be related to both upstream and downstream depths. Hydraulic model tests were made to calibrate the three weirs for a wide range of free-flow and submerged conditions.

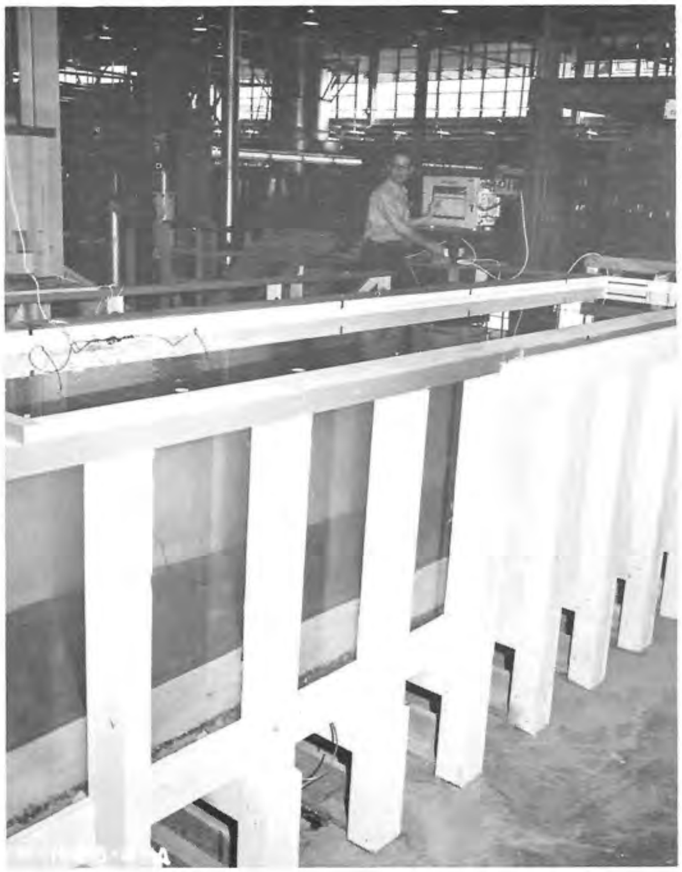

Figure 12. Seepage loss detection by electrical logging techniques was studied in a wooden flume thereby reducing the possibility of interference of measurements by magnetic fields.

Figure 13. Hydraulic tractive force measurements were made in three test reaches of the Farwell Main Canal. A vane shear measurement of the canal bottom soil is being made.

Flow Resistance Tests at Carter Lake Test Station

A field test station constructed west of Berthoud, Colorado, near Carter Lake Reservoir to study ways of controlling aquatic weeds is being used for hydraulic flow resistance tests. Ten channels 150 feet long, 1 foot wide, and 2 feet deep and having concrete sides and soil or concrete inverts were installed for growing aquatic weeds. The system was provided with weirs, gates, and bypasses for measuring and controlling the flow through the weed channels. An engineer from the Hydraulics Branch is conducting tests to determine the change in hydraulic frictional resistance caused by growth of aquatic weeds of algae. To accomplish this, four of the weed channels were provided with covered concrete wells to protect and contain hook gage wells and mounting bolts to which brackets were installed for supporting a portable hook gage. Initial hydraulic measurements to be used for computing resistance coefficients were obtained before any weed growth had occurred, and hydraulic measurements will be made periodically during the weed growing season. These measurements are planned to provide information on the relationship of accumulated biological growth and head loss in canals.

Curved Channel Study

Mr. Abdul Tawab Assifi, an administrative hydraulic engineer of the Helmand Valley Authority, Afghanistan, who was also a graduate student in civil engineering at Colorado State University, worked 3 months in the Hydraulics Branch in the summer of 1965. He extended the studies of tractive forces in a curved channel of trapezoidal cross section. Tractive forces and velocities were made at 10 stations in the 60-foot-long canal with a 16-foot radius, 60-degree central angle, and a 2-foot bottom width (Figure 14). A Preston shear tube and a pitot velocity tube with a pressure transducer and electrical recorders were used in making the fundamental measurements. The curved channel shear and velocity studies are a part of a general study for improving the design of stable channels in erodible cohesive materials.

Gate Seal Tests

A facility has been designed to test prototype gate seals, seal clamps, and seal seats under heads of up to 600 feet of water. The facility will be used with the laboratory high head pump. Clear plastic windows in the facility will allow continuous viewing and photographing of the seal bulb while the seat is moved to effect the seal. The seal seat will be moved by a high-pressure oil system.

Draft Tube Surge Studies

During operation of powerplant turbines at other than maximum efficiency, a phenomenon is frequently observed which has been termed power or draft tube surging. This surging manifests itself in rather low frequency

Figure 14. Boundary shear distribution measurements are being made on a rigid boundary trapezoidal laboratory canal.

(30-50 cps) oscillations of the power output and of the penstock pressure. Several theoretical and empirical studies of the problem have been undertaken. However, a complete explanation for the cause of the phenomenon is still not forthcoming. In an effort to correlate model data with prototype results, and thus gain more insight into the problem, the Hydraulics Branch, in cooperation with the Hydraulic Machinery Branch, has initiated a model study of the Fontenelle Dam draft tube. The Fontenelle Powerplant will be used for reservoir regulation during the summer of 1966 and, for this purpose, the turbine runner will be removed. The choice of this installation greatly simplifies the model since the turbine runner does not have to be simulated. A large number of references have been accumulated and planning of the model is in the final stages.

Design and Research on Stilling Basins

Recent operation of Bureau structures has disclosed extensive damage to concrete surfaces or appurtenances by abrasion, vibration, and in some cases, cavitation in several stilling basins. An engineer from Region 2 was detailed to the Denver Office to assist in examining and evaluating the general problem of stilling basin damage. In his report the following recommendations were offered based on consideration of reported damage, particularly in the Navajo Dam hollow-jet basin, laboratory test results, and discussions with design and laboratory personnel.

1. Pursue model studies and develop required modifications of the Navajo basin with initial emphasis on developing an understanding or at least a definitive explanation of the damage including the center wall.

2. Make such confirmation tests by limited operation of the prototype basin within the bounds of safety as are indicated by model findings.

3. Develop additional documentation on actual field and operating conditions at Navajo outlet works.

4. Collect and collate data being developed by underwater surveys of various stilling basins to identify the general merits and/or shortcomings of the basin.

5. After some progress on Items 1 through 5 has been made, assemble a group directly involved in the general design of basins and recommend a common position on immediate and future procedures.

Steps have been taken to implement the aforementioned recommendations. Reasons for the concrete damage and modifications to prevent recurrent damage to the Navajo basin have been determined from model studies. Tests to evaluate different types of basins relative to abrasion are continuing. Confirmation tests are being conducted on a similar outlet works stilling basin at Yellowtail Dam because of the practical inability to unwater, instrument, and test the Navajo basin in time to provide data for the repair design. Limited releases with periodic underwater examinations have been made and other factual historical information pertaining to the operation of the Navajo basin is being compiled. An orderly program for examination of conditions below water at numerous spillways and outlet works has been initiated. Similar programs to eventually examine all large spillways and outlet works stilling basins will be undertaken. When enough information has been developed, the results will be analyzed and appropriate recommendations for the design of stilling basins will be made.

Stilling Basins for High-head Outlet Works with Slide Gate Control

A progress report was issued for preliminary studies on the development of an efficient, economical stilling basin for use with slide gate control for high-head outlet works. Design curves were developed for a simple rectangular plunge basin and comparisons were made with corresponding hydraulic jump basins. The plunge basin shows promise as an inexpensive energy dissipator where geologic conditions permit the use of an unlined basin. Studies are continuing to determine the effects of basin shape, the distribution of hydraulic forces, circulation of abrasive material, and the formulation of final design guidelines.

Modification to the Design of Hollow-jet Valve Stilling Basins

During the past few years, damage has resulted to hollow-jet valve stilling basins during normal operation. Model studies were conducted to investigate the causes of damage to an existing prototype stilling basin and to determine necessary modifications to the basin to insure against continued damage during future operation. The model verified that damage occurred on the flow surfaces due to circulation of gravel, cobbles, and boulders which entered the basin from the downstream channel (Figure 15). The area of damage depended on the discharges and tailwater depth which influenced the circulation pattern. The studies also revealed the presence of rapidly fluctuating differential heads on the center dividing wall which could result in structural damage or failure of the wall.

Modifications to the model showed that the original design could not be improved with respect to energy dissipation and stability of flow. However, the geometry of the basin increased the susceptibility to circulation of abrasive material in confined areas. The final modifications consisted of removing the converging wedges, decreasing the slope of the chute to establish a guiding surface for the bottom of

Figure 15. Measurements of dynamic pressures and vibrations are being made in a hydraulic model of a hollow-jet valve stilling basin.

the jets, and removal of the center wall to eliminate the problem of damage to that member. These modifications reduced the efficiency and stability of the basin and necessitated reduction of the allowable maximum discharge. The downstream channel will be paved and high fences installed around the basin area to essentially eliminate the possibility of abrasive material entering the stilling basin in the future.

The Role of Hydraulic Research in Water Quality Studies

Through the years the Hydraulics Branch has made a number of studies on problems related to the control of water quality on Bureau projects. With the realization that the water sources of the west will some day approach full development, with attendant problems of water quality and pollution control, preliminary plans are being developed for research in a variety of hydraulic phenomena directly related to quality control problems.

Background--

Salinity control.--The Hydraulics Branch has completed a number of studies on the salinity control problem in the delta area of the Sacramento-San Joaquin confluence in the Central Valley from 1945 to 1950. A hydraulic model was used to delineate some of the problems in controlling the salinity in the upperreaches of the tidal estuary. Also, a complex electronic analog computer was designed and built to verify the computations made for the quantity of water necessary to control the water quality downstream from the cross channel leading to the Tracy Pumping Plant. These studies were accomplished using longitudinal and transverse salinity depth traverses taken in critical slews in the delta as a reference for the analog studies. Laboratory and field research is reported in Hydraulics Laboratory Reports No. Hyd-142, 145, 155, and 242 and in a paper entitled, "Application of an Analog Computer to the Hydraulic Problems of the Sacramento-San Joaquin Delta in California," presented at the Hydraulics Division meeting November 1950, Jackson, Mississippi, by D. J. Hebert, C. R. Daum, and R. E. Glover.

Withdrawal of water from the surface of Lake Mead.--In 1956 the Hydraulics Branch published a report on the study of Stratified Flow over a Weir. This research was aimed to provide a fuller understanding of a statement made in the final report on Lake Mead evaporation studies. The statement conjectured that if it were possible to make all water withdrawals from water of the highest temperature near the surface of the reservoir a saving of approximately 8 percent in evaporation losses would be realized. A hydraulic model was studied to establish the pattern of flow over a weir especially with regard to the proportionate contributions made to the outflow by the various levels of water in a reservoir. This study was reported in Hydraulics Laboratory Report No. Hyd-425, November 1, 1956.

Removal of salt water from two-part and single-part aquifers using tile drains.--Beginning in 1963 studies were initiated on the processes of aquifer sweetening (removal of salt water from an aquifer into agricultural-type tile drains by applying fresh irrigation water to the land surface). Using a sectional two-part sand model to represent first an aquifer and later a single-part aquifer, a study was made to evaluate a formula based on the Ghyben-Herzberg principle. This principle explains the relative depths of salt water and fresh water encountered along ocean beaches. A fuller understanding of the fundamental hydraulics of horizontal drains to control salinity levels in land-locked aquifers was derived from the model studies. These studies were followed by a mathematical approach to the same problem, utilizing the relaxation method and employing the techniques of a large digital computer. The model study report is drafted Hydraulics Laboratory Report No. Hyd-541 and the relaxation method study will be presented as a paper from the ASCE Water Resources Conference in Denver, May 1966.

A two-part aquifer model with vertical pump drains is continuing in the laboratory.

Quality of water in salmon spawning beds.--Studies are in progress on hydraulic models to evaluate the critical factors believed to be necessary before salmon will use the spawning beds being provided in a large dual-purpose canal which is also a conveyance channel for irrigation water. These studies are directed toward establishing the gradation of the stone sizes in the gravel bed, determining a method for cleaning sediment from the gravel, measuring the percolation rate through the material, and determining the quantity of latent dissolved oxygen necessary for the nurture of fish eggs and small fry. These studies are being carried out with full cooperation of the Bureau of Sports, Fisheries, and Wildlife.

Dispersion in streams.--Experimental work on the use of radioisotopes in measuring discharges in irrigation canals has provided substantial data leading to the computation of diffusion coefficients and a fuller understanding of the mixing processes that occur in streams. These studies were reported in Hydraulics Laboratory Report No. Hyd- 527, dated October 22, 1964.

Present and Future Studies--

Present studies.--The growing demand for sediment-free water and water at controlled temperatures has made it imperative that stratified flow in reservoirs be studied. At certain times of the year, the downstream water users require warm water for use in irrigating certain crops; at other times, cooler water during the fish spawning season might be needed. To meet these growing demands for temperature-controlled or selected waters, a knowledge of the movement of water through reservoirs is needed.

The studies include the effects of reservoir geometry and tributary waters on temperature stratification, the effect of stratification on the oxygen content and biologic growth, and the determination of selective withdrawal techniques. Techniques to prevent the collection of toxic chemicals in trap areas of reservoirs are contemplated. Various methods of changing stratification patterns, such as by submerged barriers and air curtains, may be studied. Because air and water are both fluids, such research may have application to problems in meteorology; for example, air pollution and the location of industry.

Future studies.--Laboratory studies and field observations will be aimed at the development of methods for predicting annual variations in the vertical water temperature, dissolved oxygen, density, and velocity distribution at various longitudinal and transverse locations within proposed reservoirs.

Studies will be directed at determining the effects of locating thermal powerplants or other industrial plants that discharge pollutants (including drainage from irrigation projects) on a previously unpolluted stream or reservoir. In this connection, the Hydraulics Branch once made an estimate for a laboratory study to determine the critical factors to be considered when discharging cooling water from the AEC plant near Richland, Washington, into the Columbia River.

It is visualized that capabilities in mathematical and computer techniques being employed in Hydraulic Research could well be used for Water Quality Investigations. Surface water and ground water may be polluted by organic and inorganic material, heat from powerplants, etc., radioactive material, and other causes. Problems from such sources could be investigated by techniques using both digital and analog computers. For example, the Hydraulics Branch has recently demonstrated the feasibility of using digital computers with relaxation and hydraulic techniques to predict ground-water flow patterns. Thus, if it were determined that a source of pollution (salt water, water with a B.O.D., hot water or radioactive material) was being (or were to be) injected into an aquifer, a digital computer program could be written which would show the flow pattern of the material as it progressed through the aquifer. The program could show the position of the pollutant at any time after injection started, and thus provide valuable information for planning purposes. The program could be written for almost any combination of aquifer layers or pollutants. Negative factors to be considered are: (1) computer programs of this type are long and complex, (2) advanced concepts are necessary to write the program, (3) programs are difficult to check, and (4) considerable computer time is necessary on a large computer to solve the problem. However, no other practical way is known in which problems of this type can be solved.

A general-purpose analog computer may readily be used to investigate reasonable differential equations involving ground or surface water flow. For instance, if two streams with different discharges and pollutions meet, and it is desired to investigate the rate of change of pollution, with respect to time, in the combined discharge, an analog computer could be used. Differential equations could be established and time could be scaled to show conditions just below the junction, or to show conditions many miles downstream. The use of the analog computer to solve problems of this type is limited only by our ability to establish the desired differential equations and program the computer.

Other investigational programs could be developed using hydraulic models to guide the establishment of the difficult computer programs. Because Hydraulics Branch personnel are experienced in matters pertaining to static and dynamic water problems, mathematics, and analog and digital computers, it is certain that the Hydraulics Branch could aid materially in solving water quality problems.

SECTION VI--GENERAL DISTRIBUTIVE ACTIVITIES

A. General Description and Identification

B. Special Activities

1. Membership in technical organizations
2. Professional papers
3. Continuing education of staff
4. Exhibits

A. General Description and Identification

Costs of this office consist of three principal elements: direct charges, general administrative expense and general distributive expense. Direct-charge projects are administered through the program process while general administrative and general distributive expense costs are administered by means of the office budget. A detailed listing of the cost categories is found in Section X.

B. SPECIAL ACTIVITIES

1. Membership in Technical Organizations, Registrations, Etc. (FY66)

Name	Membership	Membership in other technical organizations	Registered professional engineer	Other
Martin	Fellow, ASCE	International Association for Hydraulic Research Colorado Chapter, Society of the Sigma Xi	Colorado No. 1086	Chairman, Water Resources Coordinating Committee, American Society of Civil Engineers, 1966-68; Member, National Advisory Committee for the International Hydraulics Congress and Hydrology Symposium, Fort Collins, Colo., 1967. Member, Program Committee, Fourth Water Resources Conference, ASCE, May 16-20, 1966, Denver. Member, Colorado Section, ASCE
Peterka	Fellow, ASCE	Colorado Chapter, Society of the Sigma Xi Reclamation Technical Club Hydraulics Division, Colorado Section, ASCE	Colorado Engineer and Land Surveyor	Member, Committee on Standards, Hydraulics Division, ASCE ASCE Representative on Work Group 4--Liquid Measurement in Open Channels by Dilution Methods, Committee TC/113 of the International Standards Organization. Member, Suggestions Subcommittee, Incentive Awards Committee. Member, Value Engineering Team #1. Reviewed two papers for Hydraulics Division, ASCE Publications Committee. Participated in Irrigation Operators Workshop --November, 1965, in Denver; and December, 1965, in Logan, Utah.

B. SPECIAL ACTIVITIES--Continued

1. Membership in Technical Organizations, Registrations, Etc. (FY66)--Continued

Name	Membership	Membership in other technical organizations	Registered professional engineer	Other
Wagner	Fellow, ASCE	International Association for Hydraulic Research U.S. Commission on Large Dams Colorado Chapter, Society of the Sigma Xi DFC Professional Engineers Group Reclamation Technical Club	Colorado	Member, Colorado Section, ASCE Chairman, Task Committee on Outlet Works Hydraulics Division, ASCE
Simmons	Member, ASCE	International Association for Hydraulic Research Colorado Chapter, Society of the Sigma Xi Reclamation Technical Club DFC Professional Engineers Group	Colorado	Member, Control Group, Task Force on Vibration in Hydraulic Structures, ASCE. Member, Hydraulics Division, Colorado Section, ASCE Reviewed two papers for Publications Committee, Hydraulics Division, ASCE Member, Central Board of U.S. Civil Service Examiners
Schuster	ASME	International Association for Hydraulic Research Colorado Chapter, Society of the Sigma Xi	Colorado	

B. SPECIAL ACTIVITIES--Continued

1. Membership in Technical Organizations, Registrations, Etc. (FY66)--Continued

Name	Membership	Membership in other technical organizations	Registered professional engineer	Other
Carlson	Fellow, ASCE	U.S. Committee, International Commission on Irrigation and Drainage Colorado Chapter, Society of the Sigma Xi Reclamation Technical Club Lt. Col, USAR, Corps of Engineers	Engineer and Land Surveyor; Colorado No. 922	Member, Hydraulics and Irrigation and Drainage Divisions, Colorado Section, ASCE Member, Denver Federal Center Professional Engineers Group
Enger	Member, ASCE	ACM (Assoc for Computing Machinery) IAHR--International Association for Hydraulics Research Denver Federal Center Professional Engineers Group U.S. Geophysical Union AAAS--American Association for Advancement of Science Denver Federal Center Technical Club ARRL--American Radio Relay League (WAØKBR)	Colorado, No. 3195	

B. SPECIAL ACTIVITIES--Continued

1. Membership in Technical Organizations, Registrations, Etc. (FY66)--Continued

Name	Membership	Membership in other technical organizations	Registered professional engineer	Other
Rhone	Member, ASCE	Reclamation Technical Club DFC Professional Engineers Group Colorado Section, ASCE	Colorado	
Falvey	Member, ASCE	International Association for Hydraulics Research		EIT
Dexter			Colorado	
Palde	Associate member, ASCE	Colorado Section, ASCE Reclamation Technical Club	EIT, Georgia	Member, Denver Federal Center Professional Engineers Group
King	Associate member, ASCE	Reclamation Technical Club Denver Federal Center Professional Engineers Group (Secretary-Treasurer) Colorado Section, ASCE	Colorado	Candidate for M.S. Degree, University of Colorado, June, 1966
Isbester		Reclamation Technical Club		
Dodge		MICH Professional Engineers DFC Professional Engineer	EIT EIT	
Colgate	Member, ASCE	Reclamation Technical Club	Colorado	5002^{d} Research and Development, U.S. Army

B. SPECIAL ACTIVITIES--Continued

1. Membership in Technical Organizations, Registrations, Etc. (FY66)--Continued

Name	Membership	Membership in other technical organizations	Registered professional engineer	Other
Beichley	Member, ASCE	Bureau of Reclamation Technical Club U.S. Naval Reserve Research Company 9-21	Colorado	
Arris	Associate member, ASME	Reclamation Technical Club Colorado Society of Engineers		
Kuemmich		ISA--Instrument Society of America Reclamation Technical Club Colorado Mineral Society American Numismatic Society		
Zeigler		Reclamation Technical Club Denver Federal Center Professional Engineers Group	No. 6647	Passed EIT and PE Examinations June 1965 and received license September 1965

B. SPECIAL ACTIVITIES

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY66, or in Preparation

Author	Title of paper	Meeting (place and date)	Paper published
Martin	Water Resources Branch	University of Tennessee, Department of Civil Engineering, January 11, 1966	Illustrated lecture
	Present Day Trends in Water Resources Engineering	University of Tennessee, Department of Civil Engineering, January 12, 1966	Illustrated lecture
	Present Day Trends in Water Resources Engineering	The Agricultural and Technical College of North Carolina, January 14, 1966	Illustrated lecture
Peterka	Water Measurement Lecture	Irrigation Operators Workshop, November, 1965, Denver, Colorado	Delivered series of four slide-illustrated lectures to conferees
		Irrigation Operators Workshop, December 1965, Utah State University, Logan, Utah	Delivered series of four slide-illustrated lectures to conferees
	Publication--Water Measurement Procedures - Irrigation Operators Workshop 1965	Used as a handout for above Workshop Meetings	90-page illustrated paper for use with above lectures and for daily use in District and Bureau offices
	Development of Accurate Flow Measurement Procedures for High Head Turbines and Pumps Using Radioisotopes	Seventh Annual Contractors Meeting, Isotope Systems Development Program: U.S. Atomic Commission, Washington, D.C., December 6-18, 1965	Presented 2 slide-illustrated talks giving progress of our investigations in our two AEC projects utilizing radioisotopes
	Radioisotope Study of Reservoir Leakage at Anchor Reservoir		
Wagner	Surges in a Trapezoidal Canal due to Pump Flow Rejection (coauthored with D. L. King)	XI Congress, IAHR, Leningrad, Russia, September 6-11, 1965	Proceedings, XI IAHR Congress
	Trends in Water Resources Engineering	ASCE Student Chapter, State University of Iowa, March 9, 1966	

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY66, or in Preparation--Continued

Author	Title of paper	Meeting (place and date)	Paper published
Wagner	Problems in the Operation of Glen Canyon Dam Outlet Works	Graduate Seminar in Water Resources, Purdue University, March 8, 1966	
	Problems in the Operation of Glen Canyon Dam Outlet Works	Graduate Mechanics and Hydraulics Seminar, State University of Iowa, March 9, 1966	
	Reviewed paper, "Water Hammer Charts including Fluid Friction"	December 1965	For publication in Hydraulics Journal, ASCE
Simmons	Applied Research in Cavitation in Hydraulic Structures (for F. E. Dominy)	IAHR Congress in Leningrad USSR, September, 1965	Proceedings, Eleventh Congress of IAHR, September 1965
	Flow in Closed Conduits	Seminar, Southern Idaho Section ASCE, Boise, Idaho, November 1965	Proceedings, Hydraulics and Water Resources Seminar, Southern Idaho Section, ASCE, 1965
	Lecture - A Visit to Russia	PTA Meeting - Skinner Jr. High School: Denver, November 1965	
	Lecture - An Engineer's Visit to Russia	Colorado Society of Engineers, Denver, Colorado, January 1966	
	Lecture - A Comparison of Russian and American Technology	DFC Professional Engineers Group, February 1966	
	Lecture - Dams and Water	Combined science classes - West Denver High School, March 1966	
	Lecture - Comparisons of Russian and American Technology	Naval Reserve Unit - University of Denver Student Union, April 1966	
	Fluid Mechanics, I and II (a portion of the Engineer-in-Training Refresher Course)	University of Colorado Extension Center in Denver and in Colorado Springs	Lecture notes printed and distributed to approximately 105 students
Schuster	Closing discussion and digest of "Canal Discharge Measurements with Radioisotopes"	ASCE, Vicksburg, Mississippi, August 1964	Journal Hydraulics Division, ASCE, March 1965 HY2

B. SPECIAL ACTIVITIES--Continued

2. Professional Papers and Lectures Prepared, Presented and/or Published During FY66, or in Preparation--Continued

Author	Title of paper	Meeting (place and date)	Paper published
Carlson	Removal of Salt Water from Two-part and Single-part Aquifers Using Tile Drains	ASCE Annual Hydraulics Division Conference, University of Arizona, Tucson, Arizona, August 25-27, 1965	Slide and motion picture illustrated lecture presented by E. J. Carlson. Paper reproduced by USBR. Being prepared for submission to ASCE. Abstract published in "Ground Water" Vol 4, No. 1, Jan. 1966. Reviewed 5 papers for ASCE prior to publication in ASCE Journals.
Enger	Computers and Hydraulics	ASCE Environmental Engineering Conference, Kansas City, Missouri, October 18-22, 1965	Preprinted by USBR.
	Ground-water Flow by Relaxation Method	ASCE Denver Water Resources Engineering Conference, May 16-20, 1966	Sent to ASCE for preprinting.
Falvey	Surging and Cavitation Experience of the U.S. Bureau of Reclamation	Talk given to IAChE, Engineers Club, Denver, Colorado, December 15, 1965	Reviewed the paper "Analytical Solution for Turbulent Flow in Pipes" for the Committee on Publications, Hydraulics Division, ASCE, December 1964
	The Lower Colorado River Basin Project with emphasis on the Bridge and Marble Canyon Dam Sites	Talk given to the Mile High Alpine Club at their regular meeting, Evergreen, Colorado, February 11, 1966	
King	Surges in a Trapezoidal Canal due to Pump Flow Rejection (coauthored with W. E. Wagner	Eleventh Congress, IAHR Leningrad, USSR, September, 1965	In IAHR Proceedings

B. SPECIAL ACTIVITIES--Continued

2. Professional Papers and Lectures Prepared, Presented and/or published During FY66, or in Preparation--Continued

Author	Title of paper	Meeting (place and date)	Paper published
King	Development of Orifice Spillway for Morrow Point Dam (coauthored with A. T. Lewis)	ASCE Hydraulics Division Conference, Tucson, Arizona, August 1965	
	Comparison of Intake Transition Designs for a Large Pumping Plant	ASCE Water Resources Conference, Denver, Colorado, May 1, 1966	Conference preprint
	A Theoretical and Experimental Study of Rejection Surges in Trapezoidal Channels"	M.S. Thesis, University of Colorado, Spring semester, 1966	
Isbester	Hydraulic Design of Main Canal Headgate Structure by Model Study--Navajo Indian Irrigation Project, New Mexico (Coauthored by J. A. Hufferd, Canals Branch)	ASCE Hydraulics Division Conference, Madison, Wisconsin, August 1966	
Colgate	Army General Procedures for Research and Development	5002d R&D Unit, Elmer E. Fryar Reserve Center, DFC, Denver, Colorado, August 17, 1965	
Beichley	Reviewed paper for publication by ASCE Publications Committee, "Stream Flow Measurements with Fluorescent Tracers" by J. A. Replogle, Loyd E. Meyers, and K. J. Burst		Hydraulics Division Journal of the ASCE

B. SPECIAL ACTIVITIES

3. Continuing Education of Hydraulics Branch Staff (FY66)

Name	Course title and number	Type In-service--Gov, non-Gov facility or military	Place (DU, etc)	Credit yes or no	Remarks (including other studies)
Martin	Automatic Control Systems and Instrumentation	Non-Government	DU	No	Nine lectures, 2 hrs each
	Value Engineering Techniques Seminar	In-service and conducted by Harbridge House Inc. personnel	DFC	No	
Peterka	Value Engineering Techniques Seminar	In-service Govt but conducted by Harbridge House Inc. personnel	DFC	Certificate awarded	Now a member of Team 1 and working on a project--Bell-Mouth Entrance
	Irrigation Operators Workshop	Utah State Univ	Logan, Utah	Certificate awarded	Attended lectures on Water Forecast and Use, Water Delivery Problems, and Canal Lining
Simmons	Improving your Written Communications	In-service	DFC	No	
	Effective Letters	In-service	DFC	No	
	Completed 28-hr course "Management for Supervisors"				April 27 to June 10, 1966
	Completed 6-hr course "Classification"				

B. SPECIAL ACTIVITIES--Continued

3. Continuing Education of Hydraulics Branch Staff (FY66)--Continued

Name	Course title and number	Type In-service--Gov, non-Gov facility or military	Place (DU, etc)	Credit yes or no	Remarks (including other studies)
Schuster	Life Saving and Water Safety	Non-Government	Red Cross	No	
	Water Safety	Non-Government	Red Cross	No	
	Canoeing	Non-Government	Red Cross	No	
	Automatic Control Systems and Instrumentation	Non-Government	DU	No	Nine lectures, 2 hrs each
Carlson	Automatic Control Systems and Instrumentation	Non-Government	DU	No	April 30-May 25, 1966
	Command and General Staff Coll: Non-resident course	Military 5D46, USAR School	Fitzsimmons Army Hospital	Yes	Completed 4th yr of 5-yr course, August 1965
	Deputy Chief of Staff for Logistics Construction Br	In-service military	Pentagon, Wash, D.C.	Yes	Two week's active duty
	Russian Translation Seminar	In-service, Gov	Chief Engineer's Office	Yes	Completed the following translations that were duplicated by USBR--Translation No. 531, Movement of Large Range Nonuniform Mixtures of Sediment" by I. Y. Egiazarov; Translation No. 598, "Experience Utilizing Radioactive Isotopes for Measuring Discharge of Water in Pressure Conduits in Hydroelectric Powerplants" by V. A. Volokhov

3. Continuing Education of Hydraulics Branch Staff (FY66)--Continued

Name	Course title and number	Type In-service--Gov, non-Gov facility or military	Place (DU, etc)	Credit yes or no	Remarks (including other studies)
Carlson--Cont.	Supervisory Courses B-18 "Methods Improvement"	In-service, Gov	Chief Engineer's Office	Yes	Programmed, self-administered course, Completed March 1966
	Refresher First Aid Course	In-service, Gov	Chief Engineer's Office		1-hr course with emphases on mouth-to-mouth resuscitation
	"B-9" Improving Written Communications	In-service, Gov	Chief Engineer's Office	Yes	Programmed, self-administered course, Completed 5-9-66
Enger	Analog Computation and Simulation	Non-Government	CU	Yes	Just completed as FY66 started
	Improving Written Communications	In-service, Gov		No	Self-programmed course given by personnel branch
	Effective Letters	In-service, Gov		No	Self-programmed course given by personnel branch
	How to Write Effective Reports	In-service, Gov		No	Self-programmed course given by personnel branch
	Russian Translation Seminar	In-service, Gov		No	Group meets for 2 hrs/week to survey Russian periodicals and technical literature
	Automatic Control Systems and Instrumentation	Non-Government	DU	No	Course given March 30-May 25
	Discussion on basic CPM concept and demonstration of PERT-TIME problem	In-service, Gov and non-Gov lecture		No	Three hours on April 15, 1966
	Dynamic Data Analysis	Non-Government	Honeywell, Inc. Test Instruments, Denver, Colorado	No	May 16-20, 1966, 40 hours

B. SPECIAL ACTIVITIES--Continued

3. Continuing Education of Hydraulics Branch Staff (FY66)--Continued

Name	Course title and number	Type In-service--Gov, non-Gov facility or military	Place (DU, etc)	Credit yes or no	Remarks (including other studies)
Enger-- Cont.	Automatic Control Systems and Instrumentation	Non-Government	DU	No	Nine lectures, 2 hrs each
Rhone	Improving Your Written Communications	Programmed self-administered		No	
	How to Write Effective Reports	Prog self-adminis		No	
Falvey	Heat Transfer Refresher Course	Non-Government	Colorado School of Mines	No	Two-week seminar in summer of 1965
	Desalting Training Program	In-service	DFC	No	January 3-10, 1966
Dexter	Automatic Control Systems and Instrumentation, 81-490.4	Non-Government	DU	No	Spring quarter 1966
King	Beginning Russian	Government		No	After hours, USBR class
Isbester	C.E. 534-3 Hydraulics of Open Channels	Non-Government	CU, Denver Center	Yes	
	Transport Phenomena	In-service, Gov	USBR, Bldg 53	No	
	Extension Course Progessional Engineer Preparation	Military (U.S. Army Extension)			
Dodge	How to Write Effective Reports	Self-development course, Gov		No	
Colgate	Automatic Control Systems and Instrumentation, 00-831.70	Non-Government	DU	No	Nine lectures, 2 hrs each

B. SPECIAL ACTIVITIES--Continued

3. Continuing Education of Hydraulics Branch Staff (FY66)--Continued

Name	Course title and number	Type In-service--Gov, non-Gov facility or military	Place (DU, etc)	Credit yes or no	Remarks (including other studies)
Beichley	Correspondence Course "Personnel Administration"	USNR	Colo		
	Amphibious Planning	USNR-CEC	Coronado, Calif USN Amphibious Training Base		
Palde	Course in "Automath Programming"	In-service	Honeywell Co at USBR	Yes	Two weeks (10 days)--3 hrs daily from May 23 - June 3, 1966
Arris	Fortran		Jeffco Adult Education	No	
	Hydraulics of Open Channels CE-534-3	Non-Government	CU	Yes	
	Course in "Automath Programming"	In-service	Honeywell Co at USBR	Yes	Two weeks (10 days)-- 3 hrs daily from May 23 - June 3, 1966
Zeigler	Report Writing C-9	In-service, Gov	Federal Center	No	

4. Exhibits

Construction activities in exhibits were very limited this fiscal year. The regular modelmaker, after an extended vacation, elected to retire. He was engaged in model construction for only 2-1/2 months of this report period. His replacement was not employed until May 18, and has been on special assignments through June 1966.

Flaming Gorge Lake Model. The original, molds, and first copy of this 1:21,120 scale model of the lake and vicinity were completed and shipped to the Visitor Center at Flaming Gorge Dam the end of last fiscal year, Figure 16. The second copy, prepared this fiscal year for the National Park Service, was shipped December 28 to their Green River, Wyoming Contact Station.

The models depict the area in the vicinity of the lake from Rock Springs and Green River in the north to the Uinta Mountains Divide in the south. The horizontal scale is 3 inches to the mile. The vertical scale is exaggerated 2.2 to 1. Both models are for public viewing to acquaint them with the area and the facilities available.

Lake Powell Terrain Model

A meeting was held in this office on October 20, 1965, regarding the model and its appurtenances. Representatives of the National Park Service, Region 4, and this office attended. All phases of the model, its enclosure, and lighting were discussed. Agreements were reached, or the means to their end were established, on all items presented. It was also revealed that due to the unexpected retirement of our modelmaker we would have to contract with a private concern for construction of the model. There were no objections to our continued handling of the model on this basis.

The model will be in the shape of a broad Y formed by 3 concave arcs intersecting a 20-foot-diameter circle. It will include all of the Glen Canyon National Recreation Area and immediate vicinity at a horizontal scale of 1-1/2 inches to the mile. The vertical scale will be exaggerated a maximum of 2.75:1. The terrain will be portrayed as realistically as possible. Passenger car roads, scenic viewpoints, and recreational facilities will be shown. To retain the effect of realism, labeling will be minimized. Maps will be available for more detailed identification of model features or for touring the prototype.

Figure 16. 1:21,120 scale relief map of the Flaming Gorge Lake area, Utah-Wyoming.

The model will be permanently housed in the Rotunda of the Visitor Center now under construction adjacent to the right abutment of Glen Canyon Dam.

Relief Model of the Colorado River from Glen Canyon Dam to the headwaters of Lake Mead. One of the copies of this model was considerably damaged in use. The support frames, where most of the damage occurred, were partially rebuilt. Minor damage to the modeled surface was repaired.

SECTION VII--LABORATORY REPORTS, PAPERS, PUBLICATIONS, AND TRAVEL REPORTS ISSUED DURING FY66 (LABORATORY MOTION PICTURE FILMS INCLUDED)

Laboratory reports	Title	Author
Hyd-509	Hydraulic Model Studies of the Oroville Dam Powerplant Intake Structures--California Department of Water Resources--State of California--June 15, 1965	K. G. Bucher
Hyd-510	Hydraulic Model Studies of the Flood Control Outlet and Spillway for Oroville Dam--California Department of Water Resources, State of California--September 30, 1965	T. J. Rhone W. F. Arris
Hyd-521	Progress Report--Aerodynamic Study of Concrete Surface Roughness for Canal Capacity Program--December 15, 1965	J. M. Bergmann
Hyd-525	Hydraulic Model Studies of Yellowtail Afterbay Dam Spawning Channel Stilling Basin and Diffuser Chamber--Missouri River Basin Project, Montana--March 30, 1965	G. L. Beichley
Hyd-539	Hydraulic Model Studies of Granby Dam Spillway Modification--Colorado-Big Thompson Project, Colorado--May 1965	G. L. Beichley
Hyd-541	Laboratory Investigation of the Removal of Salt Water from Two-part and Single-part Aquifers Using Tile Drains--May 5, 1965 (only 10 advance copies prepared)	E. J. Carlson
Hyd-542	Hydraulic Model Studies of the Canal Transition at the Forebay Pumping Plant, San Luis Unit--Central Valley Project, California--June 15, 1965	D. L. King
Hyd-544	Progress Report VII--Research Study on Stilling Basins, Energy Dissipators, and Associated Appurtenances--Section 13, Stilling Basins for High-head Outlet Works with Slide-Gate Control (Preliminary Studies)--May 1, 1965	D. L. King
Hyd-545	Investigation of the Effect of Turnout Geometry on the Registration Accuracy of a Propeller-type Open-flow Meter--May 28, 1965	C. E. Brockway

Laboratory reports	Title	Author
Hyd-546	Hydraulic Model Studies of Surges Developed by Rejection of Flow at the Forebay Pumping Plant--San Luis Unit--Central Valley Project, California--November 1, 1965	D. L. King
Hyd-548	Hydraulic Model Studies of Swift Dam Spillways--Pondera County Canal and Reservoir Company, Montana--November 24, 1965	G. L. Beichley
Hyd-549	Hydraulic Model Studies of the Pressure-Relief Panels in the Powerplant Intake Structure--Oroville Dam--California Department of Water Resources--State of California--September 15, 1965	D. Colgate
Hyd-550	Interim Report--Sediment Tests on Prototype Diversion Dams--Kansas River Basin, Kansas-Nebraska--December 1964	E. J. Carlson E. L. Pemberton
Hyd-551	Hydraulic Model Studies of the Azotea Tunnel Inlet Junction--San Juan-Chama Project, Colorado--December 17, 1965	H. T. Falvey
Hyd-552	Water Measurement Procedures--Irrigation Operators' Workshop--1965--November 15, 1965	A. J. Peterka
Hyd-553	Vertical Adjustable Weir--March 1, 1966	J. C. Schuster
Hyd-554	Hydraulic Model Studies of the Spillway and Outlet Works for Lower Two Medicine Dam--Blackfeet Indian Irrigation Project, Montana--January 3, 1966	D. L. King
Papers and publications		
PAP-205	Removal of Salt Water from Two-part and Single-part Aquifers Using Tile Drains (ASCE Hydraulics Division Conference, Tucson, Arizona, August 25-27, 1965)	E. J. Carlson
PAP-206	Computers and Hydraulics (ASCE Environmental Engineering Conference, Kansas City, Missouri, October 18-22, 1965)	P. F. Enger

Papers and publications	Title	Author
PAP-207	Factors Influencing Flow in Large Conduits (Report of the Task Force on Flow in Large Conduits of the Committee on Hydraulic Structures) (Journal of the Hydraulics Division, ASCE, Vol. 91, No. HY6, November 1965, Paper 4543)	F. B. Campbell T. J. Rhone J. E. Schumann, Jr. F. L. Lawton, Chmn
PAP-208	Flow in Closed Conduits (A paper presented at the Seminar sponsored by the Southern Idaho Section, ASCE, in Boise, Idaho, November 18-19, 1965)	W. P. Simmons
PAP-209	A Theoretical and Experimental Study of Rejection Surges in Trapezoidal Channels (M.S. Thesis--University of Colorado--1966)	D. L. King
PAP-210	Modeling Horizontal Drains and Vertical Impermeable Barriers for an Experimental Study of Controlled Seepage, by V. I. Aravin and T. D. Strel'tsova (Russian) USBR Translation No. 537	P. F. Enger (translator)
PAP-211	Analysis of Cole Pitometer Discharge Measurements Using Electronic Digital Computers (Memo to H. M. Martin) August 6, 1964	C. E. Brockway
PAP-212	Model Study Conducted September 10, 1964, Regarding Water Conveyance Tests--Delta-Mendota Canal--Central Valley Project, California (Memo to Chief, Hydraulics Branch) September 17, 1964	P. F. Enger D. L. King
PAP-213	Critique of Three Exotic Proposals Intended to Reduce Friction Losses in Large Conduit (Memo to Files) October 28, 1964	H. T. Falvey
PAP-214	Movement of Large Range Nonuniform Mixtures of Sediment by I. V. Egiazarov (Translation No. 531) May 1965	E. J. Carlson (translator)
PAP-215	A practical Method of Calculating the Inflow of Water into a Foundation Pit Surrounded by Multilayer Soil, by M. L. Sheikov and V. A. Zel'brandt (Russian) USBR Translation No. 560	P. F. Enger (translator)

Papers and publications	Title	Author
PAP-216	Hydraulics Branch Summary Report--Fiscal Year 1964	H. M. Martin
PAP-217	Hydraulics Branch Summary Report--Fiscal Year 1965	H. M. Martin
PAP-218	Ground-Water Flow by Relaxation Methods (ASCE Water Resources Engineering Conference, Denver, Colo, May 16-20, 1966--Conference Reprint 361)	P. F. Enger
PAP-219	Hydraulic Design of a Channel Adapted to Use as a Salmon Spawning Facility (Paper presented at ASCE Hydraulics Division Conference, Tucson, Arizona, Aug 25-27, 1965)	D. J. Hebert
PAP-220	The Mechanics of Aquifer Sweetening (Paper presented at ASCE Hydraulics Division Conference, Tucson, Arizona, Aug 25-27, 1965)	R. E. Glover
Travel reports		
TR-3024	Preparation of piexometer test facilities in River Outlet No. 3 and measurement of bell-mouth pressures in the tunnel plug outlet works--Glen Canyon Dam--Glen Canyon Unit--Colorado River Storage Project (July 7, 1965)	R. B. Dexter
TR-3028	Chemical sealant treatment and ponding seepage tests--Canal A, Fort Clark Unit--Missouri River Basin Project--Lower Cost Canal Lining Program (July 6, 1965)	E. J. Carlson
TR-3034	Inspection of left diversion tunnel--Glen Canyon Dam--Upper Colorado River Storage Project (August 2, 1965)	O. L. Rice R. W. Whinnerah W. E. Wagner
TR-3043	Field inspection--Glen Canyon Dam and Powerplant--Glen Canyon Unit--Colorado River Storage Project (August 9, 1965)	H. G. Arthur R. T. Larsen A. T. Lewis E. A. Lindholm A. J. Peterka H. E. Sheda

Travel reports	Title	Author
TR-3045	Flow distribution studies in the evaporators of the Roswell demineralization plant--Roswell, New Mexico (August 9, 1965)	W. P. Simmons
TR-3059	Seismic tests--Two Forks damsite--Upper South Platte Unit, Investigations--Missouri River Basin Project, Colorado (September 9, 1965)	D. Wantland R. H. Kuemmich
TR-3065	Seismic measurements of bedrock depth in the emergency rehabilitation of the water supply for the city of Cripple Creek, Colorado (September 3, 1965)	D. Wantland R. H. Kuemmich
TR-3073	Participation in ASCE Hydraulics Division Conference, Tucson, Arizona, August 25-27, 1965 (September 11, 1965)	E. J. Carlson
TR-3085	Measurements on tractive force test reaches--Lower Cost Canal Lining Program--Farwell Main Canal--Farwell Unit--Middle Loup Division--Missouri River Basin Project (Sept 28, 1965)	E. J. Carlson E. R. Ziegler
TR-3090	Seismic measurements to evaluate tunnel wall blast damage at Two Forks Damsite--Upper South Platte Unit Investigations--Missouri River Basin Project, Colorado (October 13, 1965)	D. Wantland R. H. Kuemmich
TR-3098A	Attendance at ASCE Annual Meeting and Environmental Engineering Conference, Kansas City, Missouri--Oct 18 through 22, 1965 (Oct 29, 1965)	P. F. Enger
TR-3100	Inspection of stilling basin at Folsom Dam--Folsom Field Division--Central Valley Project (October 12, 1965)	E. A. Lindholm
TR-3109	Coordination Conference on research activities between Tennessee Valley Authority, the Corps of Engineers, and Bureau of Reclamation--Oct 12-14, 1965--Vicksburg, Mississippi (Nov 10, 1965)	G. E. Burnett H. M. Martin E. C. Higginson H. J. Gibbs F. R. Schleif L. O. Timblin, Jr.

Travel report	Title	Author
TR-3114	Hydraulics and Water Resources Seminar by the Southern Idaho Section, ASCE, in Boise, Idaho, November 18-19, 1965 (Nov 26, 1965)	W. P. Simmons
TR-3115	Examination of cavitation damage to gates and liners in Left Diversion Tunnel and examination of other gates and valves at Glen Canyon Dam--Colorado River Storage Project (Oct 6, 1965)	D. Colgate W. H. Kohler
TR-3125	Piezometric measurements of hydraulic friction and bend losses in River Outlet No. 3, Glen Canyon Dam--Colorado River Storage Project (Dec 20, 1965)	R. B. Dexter D. Colgate
TR-3126	Installation of pressure transducers and accelerometers in the center wall of the river outlets stilling basin--Yellowtail Dam--Missouri River Basin Project (December 22, 1965)	R. B. Dexter D. L. Misterek
TR-3130	Attendance at Eleventh Congress, International Association for Hydraulic Research, Sept 6-11, 1965, in Leningrad, USSR, participation in study tours, and visits to European hydraulic laboratories (December 15, 1965)	W. E. Wagner W. P. Simmons
TR-3138	Participation in Irrigation Operators' Workshop, Utah State University, Logan, Utah, Dec 1-3, 1965 (January 10, 1966)	A. J. Peterka
TR-3141	Participation in a maximum capacity test of the Gila Gravity Main Canal--Gila Project, Arizona (January 11, 1966)	R. B. Dexter
TR-3142	Pressure measurements--Outlet works stilling basin center wall--Yellowtail Dam, Missouri River Basin Project (December 27, 1965)	J. C. Schuster R. H. Kuemmich
TR-3144	Participation in Isotopes Systems Development Program, U.S. Atomic Energy Commission, Washington, D.C. (January 11, 1966)	A. J. Peterka

Travel report	Title	Author
TR-3150	Engineering representative visits--College Recruitment Program--Jan 11-14, 1966 (Jan 24, 1966)	H. M. Martin
TR-3152	Observation of structures and spillway releases--Salt River Project, Arizona (January 28, 1966)	A. T. Lewis A. J. Peterka
TR-3153	Trip to Priest Rapids spawning channel, Washington; and meeting with Bureau of Commercial Fisheries, Portland, Oregon, Concerning cleaning spawning gravels from Tehama-Colusa Canal, Central Valley Project (January 24, 1966)	J. C. Gilbert E. J. Carlson
TR-3163	Hydraulic turbine acceptance test--Flaming Gorge Powerplant--Colorado River Storage Project--(March 2, 1966)	E. H. Johnson A. E. Rickett R. H. Kuemmich
TR-3168	Pressure measurements--Lateral 6.5, South Gila Unit--Gila Project, Yuma, Arizona (March 8, 1966)	J. C. Schuster R. H. Kuemmich
TR-3174	Pressure measurements--Lateral 6.5, South Gila Unit--Gila Project, Yuma, Arizona, January 1966 (March 21, 1966)	J. C. Schuster R. H. Kuemmich
TR-3180	College contact information (April 1, 1966)	W. E. Wagner
TR-3193	Pressure measurements--Laterals 5.4 and 3.0-1.1, South Gila Valley Unit--Gila Project, Yuma, Arizona--February 1966 (May 9, 1966)	J. C. Schuster R. H. Kuemmich
TR-3195	Pressure and accelerometer measurements--Outlet works stilling basin--Yellowtail Dam--Missouri River Basin Project (May 6, 1966)	R. B. Dexter
TR-3198	Yellowtail Dam outlet works stilling basin hydrodynamic measurements with a maximum discharge of 3,100 cfs--Yellowtail Unit--Missouri River Basin Project (May 27, 1966)	R. B. Dexter R. H. Kuemmich

Laboratory Films Made during FY66

Feather River Project.--Oroville Dam flood control outlet and spillway, 300 feet of color film (at 24 frames per sec) were taken showing operation of the 1:78 scale model. Views were shown of approach flow, flow through the outlet bays, along the chute, and into the Feather River. About 2,000 feet of unedited original film, taken during the course of the model studies and about 1,600 feet of edited and titled film, selected from duplicate copies of the original film, was sent to the Department of Water Resources, State of California.

Patillas Spillway.--Six hundred feet of color film taken at 24 frames per sec showing the operation of the spillway as would occur in the existing spillway for flows ranging from 5,000 to 81,000 cfs (not edited).

Trinity Dam Outlet Works.--Color films of the prototype operation, as taken in FY64, has been edited and caption titles inserted.

Navajo Dam Outlet Works.--Four hundred fifty feet of color film of model operation with original configuration and two hundred seventy feet of color film with recommended modified configuration. Film speed 64 f/s. Not edited or captioned.

Tehama-Colusa Gravel Cleaning.--Baffle gate cleaning device for cleaning fine sediment from spawning gravel to be placed in the bottom of Tehama-Colusa Canal. Tests made in 8-foot-deep by 4-foot-wide laboratory flume. Scenes observing baffle gate moving upstream and washing gravel under the gate. Approximately 500 feet, 16 mm, color, 24 f/s, not edited, July 1966.

Yellowtail Dam Outlet Works Stilling Basin.--One hundred feet of 16 mm color film at 24 f/s, of flow conditions at outlet end of the stilling basin and riprap bank immediately downstream during 3,100 cfs release with a reservoir head of 245 feet of water on the hollow-jet valves. Not edited, July 1966.

El Vado Outlet Works Flip Bucket.--Six hundred feet of color film at a speed of 64 frames per second were taken of outlet works operation and combined spillway and outlet works operation for the 1:30 scale model. Outlet works releases were varied from approximately 800 to 7,400 cfs, and spillway releases were varied from 6,000 to 16,000 cfs. Not edited.

SECTION VIII--COMPUTER TECHNIQUES AND DATA ACQUISITION

Advanced Planning for ADP Equipment

A study is underway to make a thorough and responsible assessment of ADP equipment needed to meet future requirements of the Research Division. This study, being coordinated by P. F. Enger, is part of a more comprehensive survey of equipment needed to meet future requirements of the Bureau. One interesting portion of the study deals with benefits to be expected from a real time data collection, reduction, and control system.

The following is a partial list of digital computer programs currently under development or in use by the Hydraulics Branch:

- Seepage measurements from canals
- Fall velocity of particles in water
- Channel volume and wetted surface areas
- Variations in hydraulic model pressures
- Water surface drawdown profile
- Backwater profiles
- Venturi meter calibration
- Roughness calculations for conduits
- Downpull on hydraulic model gates
- Discharge measurements with radioisotopes
- Critical depth flume
- Depth factors for inlet buckets
- Ground-water model
- Best fit curves
- Air demand for jet-flow gates
- Model velocity calculations
- Tractive force tests
- Cole pitometer discharge
- Open-flow meter registration tests
- Preston tube data

Analog Computer

Both digital and analog computers are excellent calculating tools for certain types of problems. For instance, the digital computer is ideal for the reduction of digital data. However, analog computers are especially well suited for the time solution of specific types of mathematical equations, for the simulation of physical systems and/or subsystems, and for the control of physical processes. As the research divisions often construct models to simulate physical systems, and at present is actively studying control systems, the analog computer is especially suited to our needs.

A. Recording data in the laboratory.

B. Transferring data to punchcards.

C. Reducing data using the computer.

D. Interpreting results from computer.

Figure 17. Computer utilization by Reclamation Laboratories.

A 20-amplifier general purpose analog computer has been in use for several years. As use of the computer increased, many problems were encountered in which additional integrators and nonlinear devices were desirable. It became evident that maximum flexibility would be achieved if a larger analog computer, which could be used independently, were to be obtained. It was also evident that several prepatch panels and patch kits would prove desirable if several different people were to obtain the maximum advantage from the computer.

The larger computer, acquired in June 1966, consists of the following equipment:

- Wired desk top console with voltmeter readout and pushbutton switching
- Necessary power supplies
- 50 operational amplifiers
- 16 integrator networks
- 70 coefficient setting potentiometers
- Repetitive operation facilities
- 5 single-pole, double-throw, center-off function switches
- Electronic digital voltmeter
- 4 high-speed, double-pole, double-throw, relay type comparators
- 5 quarter-square multipliers
- 3 variable diode function generators
- 4 log diode function generators
- 2 X^2 diode function generators
- 8 free diodes
- 6 prepatch panels
- 6 patching kits
- 6 operating manuals
- 1 X-Y recorder

Computers and Hydraulics

P. F. Enger presented a paper, Computers and Hydraulics, at the Fall Meeting, ASCE, at Kansas City, Missouri, in 1965. The abstract of the paper follows:

Experience using computers for simple and complex hydraulic problems showed that direct application of computers to everyday problems in a small engineering office is practical and easily established with reasonable effort. After about 30 hours training in a mathematically oriented programing language, most engineers were able to program their work for electronic digital computers, making programs for small routine problems practical. Most programs were small, but compared with manual methods, the time saved with each added to significant savings in man-days. Engineers were thus freed for professional tasks, and added work was undertaken. Suggestions for computer application in small offices include: (1) using formal teaching methods to instruct engineers in a mathematically oriented programing language, (2) encouraging engineers to write their own programs for small problems, (3) obtaining the services of professional programers when difficult generalized problems are involved, (4) making the computer readily available to the staff, and (5) obtaining cooperation of the staff. Engineers trained in programing will attack complex problems previously impractical because of excessive arithmetical operations.

SECTION IX--PERSONNEL

Regular Staff--Hydraulics Branch

Harold M. Martin, BSCE, MSCE, PE, Chief of Hydraulics Branch
Alvin J. Peterka, BSCE, PE, Head of Section
William E. Wagner, BSCE, MSCE, PE, Head of Section
Enos J. Carlson, BSCE, MSCE, PE, Hydraulic Research Engineer
Jack C. Schuster, BSME, MSME, PE, Hydraulic Research Engineer
William P. Simmons, BSME, PE, Hydraulic Research Engineer
Thomas J. Rhone, BSCE, PE, Hydraulic Research Engineer
Robert B. Dexter, BSME, PE, Research Hydraulic Engineer
Phillip F. Enger, BSCE, MSCE, PE, Research Hydraulic Engineer
Henry T. Falvey, BSCE, MSCE, Dr-Eng., Hydraulic Research Engineer
Glenn L. Beichley, BSCE, MSCE, PE, Hydraulic Research Engineer
Russel A. Dodge, Jr., BSCE, Hydraulic Research Engineer
Danny L. King, BSCE, MSCE, PE, Hydraulic Research Engineer
Donald Colgate, BSCE, Hydraulic Research Engineer (PE)
Charles E. Brockway, BSCE, MSCE, Hydraulic Research Engineer (1)
Uldis J. Palde, BSCE, Hydraulic Research Engineer
Eugene R. Zeigler, BSCE, PE, Hydraulic Research Engineer
Wayne F. Arris, BSME, Hydraulic Research Engineer
Thomas J. Isbester, BSME, Hydraulic Research Engineer
Robert H. Kuemmich, Electronic Development Technician
Howard R. Schroeder, Visual Information Specialist
James E. Fay, Hydraulic Engineering Aid (2)
Julius P. Ambrusch, Exhibits Specialist (2)
Lysle L. Frey, Exhibits Specialist
Laura S. Hawthorn, Secretary

E. R. Holley, Jr., Dr. Sc., started a 15-month assignment in the Hydraulics Branch by arrangement of the Ford Foundation and the University of Illinois

Mr. Keith H. Denson, of the Civil Engineering staff, Mississippi State University began 3-month appointment in June 1966

Donald L. Simmonds, Mechanical Engineer, was assigned on detail from the Mechanical Branch for 90 days

(1)Resigned August 1965.
(2)Retired December 31, 1965.

Rotation Engineers:

Michael R. Schaefer
Larry D. Morton
Warren A. Smith
W. P. Gersch
Paul F. Carlson
Paul C. Luning Jr.
Fred W. Opp

R. I. Fugimoto
E. C. Agy
R. E. Haefle
J. S. Watkins
Robert D. Nelson
J. W. Miller

Recapitulation of Staff Statistics

Date	Permanent employees	Total annual salaries	Temporary employees	Military furlough	Trainees	On detail	Educational leave
1-1-51	47	$211,885	-	1	6	-	-
1-1-52	41	219,035	-	2	1	1	1
1-1-53	39	219,445	-	1	1	-	-
1-1-54	30	178,145	-	1	3	-	-
7-1-54	25	162,170	-	1	-	2	-
7-1-55	21	127,000	-	2	-	-	-
7-1-56	20	134,595	1*	2	3**	-	-
7-1-57	22	153,735	1*	-	3**	1	-
7-1-58	21	173,505	2*	-	1**	1	-
7-1-59	20	167,410	-	-	-	-	-
7-1-60	23	188,977	-	-	1*	-	-
7-1-61	24	205,660	-	-	-	-	-
7-1-62	22	185,405	-	-	-	-	1
7-1-63	23	219,605	1*	-	-	-	1
7-1-64	24	236,955	-	-	-	-	1
7-1-65	23	243,130	-	-	2	-	0
7-1-66	22	245,748	2	-	2	-	0

*University faculty members employed during summer months.
**Engineering students working during summer months.

In addition, Fred A. Chavez and Reginald E. Mitchell were employed part time during school year. Temporary employees in June 1966 were K. H. Denson and R. E. Mitchell. Summer trainees 1965 were D. R. Cooper and D. E. Fleming.

SECTION X--TIME AND COST DISTRIBUTION BY CLASSIFICATION OF WORK SUMMARY FOR FY66

This section consists of three parts as follows:

A. Percentage of Labor Distribution for FY66
B. Labor and Additive Expenditures--FY66
C. Water Resources Engineering Research--Monthly Cost Report--June 30, 1966.

DIVISION OF RESEARCH

A. Percentage of labor distribution July 1, 1965 through 6-30-66

	Elec Pwr.	Conc-Stru.	Chem	Hyd.	Soils	Water Cons.	Lab. Svc.	Division Actual	Division Budget	Rate of Expend.
RECT CHARGE - TOTAL	95.1	93.6	94.4	91.0	89.9	96.9	65.2	90.5	90.8	
ureau Projects	26.1	56.6	47.8	21.7	58.6	10.3	25.5	43.0	43.4	
tside Agencies	–	13.7	14.1	7.4	0.9	38.0	13.7	12.1	11.1	
reign Activities	–	0.5	0.4	3.9	0.5	–	3.3	1.1	1.5	
abrication Orders	–	0.2	–	–	–	–	5.1	0.5	0.4	
search	66.1	13.4	24.3	45.3	26.2	48.0	17.0	26.7	28.3	
eneral Admin. Expense (GAE)	2.9	9.2	7.8	12.7	3.7	0.6	0.6	7.1	6.1	
Bureau Staff Supervision	–	1.6	1.6	2.1	1.4	0.1	0.1	1.4	1.5	
Prep. of Project Data	–	–	–	0.4	–	–	–	0.1	0.1	
Prep. Manuals, Std. & Guides	–	1.0	–	2.1	–	–	–	0.6	0.7	
Prof., Gov't, & Civic Actv.	2.9	2.7	0.7	3.5	1.0	0.2	–	1.8	0.8	
Bur. Conf. & Training	–	0.3	0.1	0.6	0.1	–	–	0.2	0.2	
Personnel Services	–	0.1	0.1	0.5	0.1	–	–	0.1	0.2	
Tech. Info. Services	–	3.5	5.3	3.5	1.1	0.3	0.5	2.9	2.6	
ENERAL DISTRIBUTIVE ENSE - TOTAL	5.0	6.4	5.4	9.0	10.1	3.0	34.9	9.5	9.1	
eneral Operating Expense	3.4	4.5	3.0	4.0	4.8	0.7	34.9	6.7	6.5	
mployee Benefits & Welfare	3.4	0.1	0.2	0.4	–	0.3	–	0.3	0.1	
Equipment Maintenance	–	3.9	2.4	3.1	4.1	0.1	34.4	5.9	5.9	
Bldg. Maint. & Alter.	–	0.2	0.1	0.1	–	–	0.3	0.1	0.1	
Misc. Admin. Expense	–	0.3	0.3	0.4	0.7	0.3	0.2	0.4	0.4	
Indirect Engineering Expense	1.6	1.9	2.4	5.0	5.3	2.3	–	2.8	2.6	
Technical Studies	–	0.1	0.2	1.3	3.3	0.5	–	0.8	0.8	
Staff Development	1.6	1.2	1.1	3.7	2.0	1.8	–	1.6	1.5	
Tech. Stds. & Procedures	–	0.6	1.1	–	–	–	–	0.4	0.3	

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B. LABOR+ADDITIVE EXPENDITURES--FISCAL YEAR 1966

Hydraulics Branch Cost Center 830 Date of this report 6-30-66

Feature	Job Number	Labor+additive Annual Budget	Labor+additive Expended to date	% spent in 100 % of time, Branch	% spent in 100 % of time, Division	rate of expenditure
Bureau Project Work		44640	66680	149.4	102.0	
Outside Agencies		25,000	22880	91.5	111.9	
Foreign Activities		18,000	12,050	66.9	78.7	
Fabrication Orders	01-0-7001-00-					
Water Resources Engr Research						
Aquatic weed control	18-0-801-76-01-01					
Coatings and sealers	02-01					
Plastics	02-02					
Chemical techniques	02-03					
Petrographic techniques	02-04					
Applied physics	02-05					
Corrosion processes	02-06					
Bituminous & petrochemicals	02-07					
Turbine flow measurements	02-08	1500	1201			
Concrete	03-01					
Cement & pozzolan	03-02					
Electric power	04-01					
Evaporation reduct. (Gen.)	05-01					
Contract Adm. (Evap)	05-02					
Lake Hefner study	05-03					
E[lephant] Butte study	05-04					
Hydraulics	06-01	127840	124729			
Sedimentation	06-02					
Water meas. devices	06-03					
Turbine flow measurements	06-14	2850	1471			
LCCL	08-01	11720	11719			
Earth	10-01					
Riprap	10-02					
Structural	11-01					
Rock foundations	11-11					
Water chemistry--General	12-01					
Lake Mead Limnology	12-02					
Cheney Reservoir (Water Qual)	12-03					
Foss Reservoir (Water Qual)	12-04					
	06-16		185			
		143,400	139,305	97.1	97.1	
Employee Incentive Awards Program	01-0-3000-00-02-01	1200	1253	104.4	253.4	
Equipment Maintenance						
Office equipment	01-0-3000-00-03-01	400	336			
Laboratory equipment	03-03	9300	7447			
Technical equipment	03-04	1900	1646			
		11600	9429	81.3	103.1	
Bldg. Maint. & Alterations	01-0-3000-00-04-	200	199	99.5	103.6	
Misc. Admin. Expense						
Office moves	01-0-3000-00-08-07	500	365			
Details to Washington	08-09					
Safety meetings	08-10	1400	993			
		1900	1358	71.5	98.1	

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..ev. 8-65 Cost Center 830 Date of this report 6-30-66

Feature	Job Number	Labor-additive Annual Budget	Labor-additive Expended to date	% spent in 100 % of time Branch	% spent in 100 % of time Division	Rate of Expend-iture
Technical Studies						
ADP-Auto. of Soils Lab.	01-0-~~3100~~ 6100-00-~~01-12~~ 72-32	2700	3792	140.4	104.5	
Staff Development	01-0-3100-00-01	500	126	25.2	113.7	
Rotation Engineer Training	01-0-3100-00-02-02	7500	5952			
In-service train.-Bureau	02-04	2600	3882			
Train. in non-gov't facil.	02-05	1000	1561			
ADP training courses	02-06					
		11,100	11,395	102.7	107.8	
Tech. Stds and Procedures	01-0-3100-00-03-	200	97	48.5	118.2	
ureau Staff Supervision						
General Staff Supervision	71-0-9300-00-02-01	7000	6571	93.9	93.9	
Safety Program	05-01					
Office of Engrg Reference	13-01					
rep. Manuals, Standards & Guides						
Reclamation Instructions	71-0-9301-00-01-01					
Concrete Manual	02-01					
Earth Manual	03-01					
Paint Manual	04-01					
Water Measurement Manual	05-01	7000	6354	90.8		
c. Lab. Procedure Manual	11-01					
					86.1	
Prep. of Project Data	71-0-9302-00-01-	2000	1133	56.7	56.7	
rof., Governmental & Civic Activities						
Attendance at meetings	71-0-9303-00-01-01	3000	5347			
Technical papers	02-01	200	438			
Fed., state & local groups	03-01	1500	2824			
Tech. group participation	04-01	300	2188			
		5000	10797	215.9	239.4	
ureau Conferences & Training						
Train. bureau field pers.	71-0-9304-00-02-01					
Meeting-Irrig. Operators	03-01	1800	1845	102.5		
					91.6	
Personnel Services	71-0-9305-00-01-	1500	1671	111.4	80.6	
echnical Information Service						
Exhibits and displays	71-0-9307-00-01-01	1000	591			
Foreign visitors	02-01	1500	1526			
Domestic visitors	03-01	3500	2104			
Lab & office tours	04-01	450	966			
Technical inquiries	05-01	5500	2856			
Articles and papers	06-01	300	1650			
Monograpns & tech. memos	07-01	3000				
Misc. Tech. publications	08-01		1187			
		15,250	10,880	71.3	113.3	
		300,000	307,815	102.6	102.9	

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Program Coordination Branch
C. WATER RESOURCES ENGINEERING RESEARCH--3
Monthly Cost Report--June 30, 1966

Production Order and Job No.	Description	Labor	Other direct costs	Distri-butive costs	Total costs	Obliga-tions	Total costs and obligations	Cost program
18-0-801-7606	HYDRAULICS							
-01	Hydraulic	135,597	13,008	39,783	188,388	2,950	191,338	187,507
-04	Canal capacity studies	2,829	635	834	4,298	-	4,298	
-05	Design criteria--Channels	1,595	70	502	2,167	-	2,167	
-06	Seepage loss equation	2,279	-	711	2,990	-	2,990	
-07	Turbine and pump testing	3,655	526	1,137	5,318	-	5,318	
-08	High velocity flow chutes	804	46	240	1,090	-	1,090	
-11	Narrow draft tube under-ground installations	-	-	-	-	-	-	
-13	Transient flow	-	-	-	-	-	-	
-14	Turbine flow measurements	5,265	7,078	1,273	13,616	-	13,616	12,500
-15	Studies of sedimentation	-	-	-	-	-	-	
-16	Studies of head losses	1,986	-	646	2,632	-	2,632	
-17	Elimination of draft tube surges	518	26	151	695	-	695	
-18	Protection of erodible channels	982	-	331	1,313	-	1,313	
	Subtotal	155,510	21,389	45,608	222,507	2,950	225,457	200007
18-0-801-7608-01	LOWER COST CANAL LINING	67,358	95,679	19,267	182,304	71	182,375	
	Subtotal	67,358	95,679	19,267	182,304	71	182,375	185,198

SECTION XI--BUDGET ESTIMATE

HYDRAULICS BRANCH
FY67 Labor and Additives

	FY66	FY67
1. Bureau Project Work	$ 54,830	$ 20,000
Region 1--$1,000; Region 2--$8,500; Region 3--None;Region 4--$6,000; Region 5--$4,000; Region 6--None; Region 7--$500		
Third G. C. Powerplant architectural model		10,000
Third G. C. Powerplant hydraulic model		15,000
Value engineering of intakes		15,000
2. Outside Agencies	25,000	
Park Service		3,000
Office of Saline Water--Pump Intake		10,000
Office of Saline Water--Erosion impingement testing		15,000
Harza Engineering Company--Valve tests		
NESCO--Undersea aqueduct		
3. Foreign Activities	18,000	
Patillas Dam spillway		10,000
Training foreign engineers		5,000
Toa Vaca Dam--Puerto Rico		
4. Water Resources Research		
Hydraulics	133,220	156,000
Turbine flow measurements 18-0-801-76-06-14		15,000
LCCL	11,720	(4,000 Gross) 3,000 L & L
Total items 1-4 inclusive		277,000
5. Employee Incentive Awards Program	1,200	1,200
6. Equipment Maintenance		
Office equipment	400	500
Laboratory equipment	9,300	9,500
Technical equipment	1,900	2,000

	FY66	FY67
7. Building Maintenance & Alterations		
Research Engineer occupancy	$ 200	$ 3,000
8. Supplies and Miscellaneous Services		
Office moves	500	500
Safety meetings	1,400	1,500
9. Technical Studies	3,200	
Value Engineering projects		3,000
Research for Washington Office special requests		2,000
10. Staff Development		
Rotation Engineer training	7,500	7,500
In-service training	2,600	3,000
Training in Non-Government facilities	1,000	1,000
11. Bureau Staff Supervision		
General staff supervision	7,000	7,000
12. Preparation of Bureau Manuals, Standards and Guides		
Water Measurement Manual	7,000	7,000
13. Preparation of Project Data	2,000	2,000
14. Participation in Professional, Governmental and Civic Activities		
Attendance at meetings	3,000	3,000
Technical papers	200	500
Other participation in Federal, State and Civic groups	1,500	3,000
Technical group participation	300	1,000

Hydraulics Branch Budget Estimate--FY67--Continued

	FY66	FY67
15. <u>Bureau Conferences and Training</u>		
Meeting with Irrigation Operators	$ 1,800	$ 2,000
16. <u>Bureau Personnel Services</u>	1,500	2,500
17. <u>Bureau Technical Information Services</u>		
Exhibits and displays	1,000	1,000
Foreign visitors	1,500	1,500
Domestic visitors	3,500	2,500
Laboratory and office tours	450	1,200
Technical inquiries	5,500	2,500
Articles and papers	300	2,500
Monographs and technical memorandums	3,000	4,000
Miscellaneous technical publications	--	1,500
Total items 5 to 17 inclusive	(68,950)	(77,400)
Total	$ 300,000	$ 354,400