A Century of USDA Irrigation Research in Colorado

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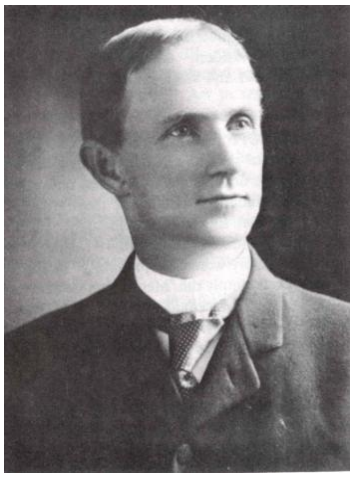
The greatest problem facing farmers of early Colorado was learning how to produce crops in what was then called the "Great American Desert." The early Spanish Americans who settled the *Rio Grande Del Norte* basin were the first Europeans to practice irrigation in Colorado. Pioneers from rainfed agricultural areas in the Eastern U.S. and Northern Europe settled later in the South Platte and Arkansas River Basins, but had little knowledge of the need for supplemental water. Water conflicts began to arise with the discovery of gold in the Colorado mountains in 1858. Both placer mining and irrigation that followed soon made clear that English water law in use back East was not appropriate here, and this realization became part of Colorado Territorial law. English or 'riparian' laws gave rights to those who owned the land through which a stream passed, which was inconsistent with the need to divert water away from the stream for placer mining or to irrigate the dry Colorado soils. Thus, the 1876 Constitution of the new State of Colorado defined a new water doctrine, that of "Priority of Appropriation." This new law guaranteed the best rights to water to those who had made legal claim first, and was eventually adopted throughout the arid West. Because of disputes over water that had developed between the towns of Fort Collins and Union Colony (Greeley) during the drought of 1874, the State established a commission to administer the new law. Thus, the area of water was already of major prominence when the Agricultural College at Fort Collins admitted its first students in the Fall of 1879.

Early Irrigation in Colorado



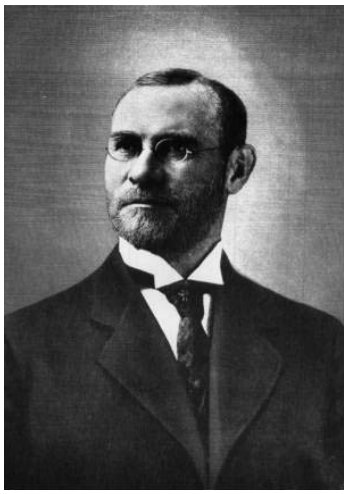
Elwood Mead, Irrigation Engineer

No such field as irrigation engineering existed in the US until 1882, when President Ingersoll of the Colorado Agricultural College hired a young engineer by the name of Elwood Mead from Purdue and Iowa Ag College. Even though he was an engineer, Mead was hired as a mathematics professor, because they commanded a lower salary than did engineers. Upon arriving in this area, Mead quickly saw the need to begin investigations and education regarding irrigation. He began to study not only why the infrastructure worked or failed, but also the "duty of water," or how much water was

1 Early history of Colorado irrigation and USDA irrigation research adapted from "*Engineering for Agriculture at Colorado State University*" by A. T. Corey, 1977.

necessary for production. Mead became probably the most prominent irrigation engineer in the US, and is the engineer for whom the reservoir impounded by Hoover dam is named. In 1888, Mead left the College for various positions, including State Engineer of Wyoming. He served as Chief of the Division of Irrigation and Drainage Investigations, USDA from 1899-1907, and later spent twelve years as Commissioner of the U.S. Bureau of Reclamation. Thus, the first real tie between USDA irrigation research and the Agricultural College of Colorado is genuinely more than 100 years old, and Fort Collins, Colorado is truly a birthplace of scientific irrigation studies in the US.

The Secretary of Agriculture established the Office of Road Inquiry on October 3, 1893, under the 1893 Agricultural Appropriation Act. This office was re-designated the Office of Public Road Inquiries in 1899, and the 1905 Ag Appropriations Act combined that office with the Division of Tests in the Bureau of Chemistry and renamed it the Office of Public Roads. In 1915, the Office of Public Roads was consolidated with the Drainage and Irrigation Divisions in the Office of Experiment Stations to form the Office of Public Roads and Rural Engineering, still under the auspices of the USDA.



Louis G. Carpenter, 1911

Mead was replaced at Colorado Ag College by Louis G. Carpenter, who also committed himself to a program of practical study in irrigation. It was Carpenter who established the College's first weather station and began observations of evaporation. By 1889, the Board of CAC had established irrigation engineering as one of only four electives for study. Among Carpenter's students were Victor M. Cone and Ralph L. Parshall, a 1904 graduate (and second violinist of the 1902 CAC orchestra!) who joined the college faculty in 1907. During his later years at CAC, Carpenter was instrumental in the design of a new civil and irrigation engineering building at the southwest side of the Oval, which housed both CAC and USDA staff. He resigned his position at CAC in 1911, but by that time had made the College **THE** place to study irrigation, a distinction it held for many decades.

Victor M. Cone, Irrigation Engineer

By 1911, USDA's Drainage and Irrigation Division had irrigation engineers stationed in several western states, including Kansas, Texas, Arizona, Utah, Idaho, California and Oregon. Victor Cone was born and reared on a Kansas farm. After graduation from CAC, he took a job as an irrigation engineer on the USDA staff in Berkeley, California. Thus, when USDA started the Irrigation Investigations Unit in 1911, Cone was an established irrigation investigator, and was selected as director. It appears that Cone's work was largely with measuring water flow and design of canals and division structures. He published several Experiment Station Bulletins, even though his title listed him as employed by USDA, and each

Ralph L. Parshall, at USDA Hydraulics Lab

of these listed the entire CAC Experiment Station staff. It's no wonder that people have since been confused for whom USDA staff work. Cone remained at Fort Collins until at least 1917. In 1918 he was in Tulsa, OK as a World War I civil engineer involved in building construction. The latest paper we find was published in 1924 as Farmer's Bulletin 813 related to design of weirs, although we have not found a copy to establish his affiliation. In 1930 he was in Memphis, TN as a hydraulic engineer with the U.S. Engineers, possibly what is now called the Army Corps of Engineers. Cone died in 1970 in Tucson, AZ.

Parshall was the son of a farmer, born at Golden, CO and reared in Jefferson County. He moved from his position as instructor at CAC to USDA research in 1913, shortly before that agency merged to become part of the Office of Public Roads and Rural Engineering. These two engineers formed the nucleus of what would become a continuous chain of USDA engineers that link to what today is the Water Management Unit of ARS. By 1915, the list of Experiment Station Personnel in irrigation publications showed E.B. House as Irrigation Engineer (later head of Civil and Irrigation Engineering, then Dean of Engineering), with V.M. Cone as Irrigation Investigations. Assistant Irrigation Investigations personnel include R.E. Trimble, Paul S. Jones, James D. Bell and Carl Rohwer, although it is not clear whether all had the same employer.

Carl Rohwer, Irrigation Engr

Carl Rohwer, a Nebraskan and Cornell graduate, if not the others named above, joined the USDA group in 1914. This team became known for studies on evaporation and evapotranspiration; for water flow measurement devices (Parshall flume which is used around the world); for devices to remove sediment from canals; for methods to design water wells and their gravel pack; and for studies of canal and ditch seepage. Much of Rohwer's work was conducted in a copper lined evaporation tank he constructed on the College farm, probably about the center of the present day Student Center. We have not determined much about Carl Rohwer, although there is record of a 2nd Lieutenant Carl Rohwer in the U.S. Army Field Artillery having served in WWI from Fort Collins.

USDA Evaporation Tank, ca 1920

Many of their early studies were conducted in two laboratories they built; the first was the USDA

hydraulics laboratory, designed and built by Cone and Parshall in 1912 and located quite distant from the main campus; just west of the current Engineering Building where the north end of the present CSU Student Center stands. This lab was probably the most significant contribution to irrigation research at the College to that date. The Bureau of Reclamation sent a team to Fort Collins in 1930 to conduct model studies for its Boulder Canyon Project (Hoover Dam) in the USDA laboratory. Many other significant model studies were conducted there by USBR and US Geological Survey over the ensuing years. After additions were built, expanding it fourfold by 1937, the hydraulics laboratory contained offices which were to serve USDA staff, both Agricultural Research Service and the Soil Conservation Service's Snow Survey until 1958.

Horsetooth Reservoir, began filling in 1951

In 1920, Parshall built a second lab at the Arthur Ditch diversion structure on the Cache la Poudre River near Bellvue. It was at this lab that the late development and calibration studies for Parshall's "Modified Venturi Flume" were conducted. Rohwer eventually lead the USDA group until his retirement in 1956. Parshall continued to teach classes and work at the Bellvue lab until his death in 1959. The lab still stands in its picturesque location beneath the Bellvue syncline along the Cache la Poudre, although it has not been used for more than three decades. The last significant studies conducted at the lab were by ARS engineer Gordon Kruse, with the help of then CSU graduate student Harold Duke, to calibrate a series of commercial steel flow measurement/turnout gates in1963.

USDA Bellvue Hydraulics Lab, 1924

In 1905, Louis Carpenter had his students perform feasibility studies to validate talk of the past 25 years of diverting water from the western slope to Northeast Colorado. In 1919, CAC President Lory recommended that the College resume research into that possibility. The drought and accompanying *Dust Bowl* of the '30s brought the need for additional water to the forefront,

and Lory and Parshall obtained a grant from Roosevelt's Works Project Administration (WPA) to conduct a full-fledged feasibility study. By 1938, the Colorado-Big Thompson Project was under construction, thanks to the cooperation between USDA, the College, and the US Bureau of Reclamation. World War II slowed the progress of construction, but did not stop the project. After the War, CBT construction kicked into high gear, and all major features were completed by 1956, including the signature East Slope reservoirs, Horsetooth and Carter Lake. The project, administered by the Northern Colorado Water Conservancy District, supplies some 220,000 acre feet of supplemental water to the lower South Platte River basin annually, which greatly improves the stability of regional agriculture.

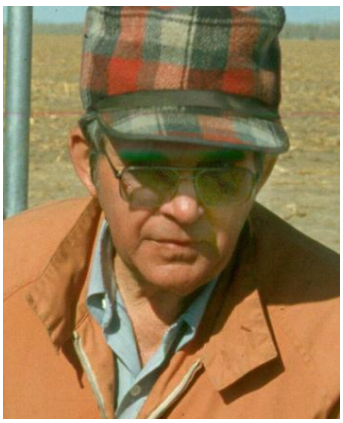
The USDA research agency went through several name changes in the ensuing decades. The Soil Erosion Service was established within the Department of Interior in 1933 as a result of the Dust Bowl which arose during the drought, affecting 75% of the United States land area. In 1935, President Franklin Roosevelt resolved a struggle between the Secretaries of Interior and Agriculture by transferring the agency, later called Soil Conservation Service, to USDA. The Bureau of Plant Industry, Soils and Agricultural Engineering (BPISAE) was transferred to the Agricultural Research Service in 1953, with some of the employees remaining in The Soil Conservation Service (which became Natural Resources Conservation Service in 1994).

A.R. Robinson, ca 1955

Following World War II, many returning GIs took advantage of the new education bill to pursue an advanced degree. Among those was a young Texan named A.R. "Robbie" Robinson. Robinson held a joint appointment with USDA and the Experiment Station after finishing graduate school in 1951, where he studied seepage from canals and developed designs for drains to intercept ground water flowing beneath irrigated lands. Robinson led the Fort Collins group after Rohwer's retirement, left Fort Collins in 1963 to open the new ARS lab in Kimberly, ID, later became director of the ARS Sedimentation Lab in Oxford, MS, and eventually became the National Program Leader for sedimentation research.

Howard R. Haise, RL, 1974

In the midst of WWII, USDA hired an Ag Engineer from Ohio State named Howard R. Haise to go to the desert paradise of Indio, California. The demand for rubber on which to move our troops was exceeding the supply from the traditional tropical tree source, and USDA was called upon to explore how to produce practical amounts of rubber from the desert shrub called *guayule* -- which would probably require irrigation to produce economical quantities. Haise spent the remaining war years learning of irrigation in California, then was moved to an equally hospitable climate in Mandan, ND before having the opportunity to transfer to Fort Collins in 1954. Haise became Research



Bud Payne, ca 1980

Investigations Leader (RIL) for Irrigation and Drainage, having responsibilities throughout the Western Region of the Soil and Water Division of ARS. Haise was deeply moved by the amount of labor involved in manual irrigation by surface methods (ie, border and furrow irrigation), and recognized that inexpensive labor was disappearing and, furthermore, was not trained to make the kind of decisions that fostered efficient use of irrigation water. He spent the last decade of his career developing and testing devices to automate these irrigation systems. About 1965, he discovered a CSU technician who was adept at most any mechanical skill, and had an inventive imagination as well. Meredith "Bud" Payne became a direct employee of ARS in 1967, and served as an engineering technician until his retirement in 1990. Haise retired in 1974, and both he and Payne continue to live in Fort Collins today.

About 1956, ARS detailed a young engineer from Boise, Idaho to Fort Collins to study for a Master's degree. R. William Nelson was apparently the first of several to be sent to Fort Collins to study at the premier irrigation school to better prepare them for their USDA careers.

In 1958, Colorado State University completed a new Engineering building just east of the USDA Hydraulics Lab, which included offices for the USDA Irrigation Unit.

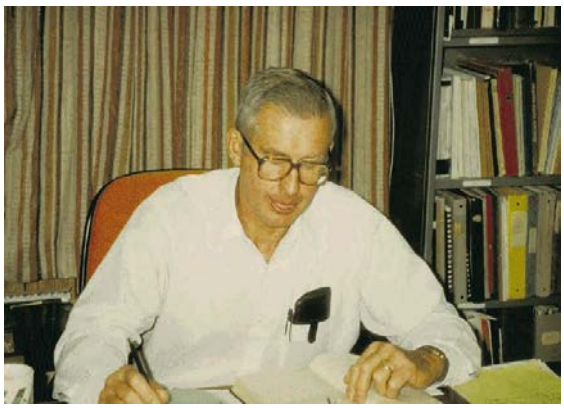
CSU Engineering Bldg, 1963

A young Ag Engineer from North Dakota named Marvin Jensen, who had begun studies of crop water use (evapotranspiration or ET) at the ARS facility in Bushland, TX, was also granted a transfer to Fort Collins under Haise to pursue a PhD degree in 1959. Jensen used data he collected while at Bushland to develop a method of computing ET, which is used worldwide and now known as the Jensen-Haise method. Haise led the group until his retirement in 1974 and still lives in Fort Collins. Jensen became a world renowned irrigation researcher and served as President of the International Commission on Irrigation and Drainage as well as the irrigation specialist on the ARS National Program Staff. Jensen also lives in Fort Collins as of this writing.

Marvin E. Jensen, 1965

One of Robinson's later students was a Nebraskan by the name E. Gordon Kruse, who joined the USDA at Colorado A&M in 1957. Kruse first worked in the area of irrigation well design and in water measurement. He later spent several years with Haise, developing devices to automate the drudgery of surface irrigation as a means of improving the efficiency of water application. In

the early 1970s, Haise and Kruse conducted studies of high mountain meadow evapotranspiration to determine how much water could be saved by stopping irrigation in these meadows in South Park and the Gunnison Valley. The eastern slope metroplex was in the process of purchasing water rights in these valleys for transfer to urban use. These studies established the difference between ET under irrigation and that from the naturally high water tables, which could be claimed for transfer. During the latter stages of this project, a major Denver consulting company was involved and assigned a young engineer named Gerald Buchleiter to collect and analyze the data in collaboration with ARS.



E. Gordon Kruse, Ag Engineer, ca 1985

In 1973, the unit established an office in Grand Junction to pursue a project with the support of the US Bureau of Reclamation. Kruse became leader of this project where he spent much of the balance of his career developing strategies for management of salinity in the arid Grand Valley. Results of these studies were the primary basis for a major irrigation system improvement project by USBR and NRCS to reduce saline return flows to the Colorado River. To conduct the day-to-day field work, the Unit hired Dan Champion, a soil chemist, and later added Dennis Kincaid, an agricultural engineer who had finished a PhD with the unit in Fort Collins. They were supported by technicians Gordon Fischbacher, Dan Cuevas and Marti Cary. Within a couple of years, Dennis cost Marti her job by marriage – ARS rules would not allow a married couple to work in the same unit. By about 1979, Dennis moved to the ARS lab at Kimberly, Idaho, from which he has recently retired, and where he and Marti continue to live. David Young, who had also received his agricultural engineering degree while working with the unit in Fort Collins, followed Kincaid at Grand Junction. Young left to open a successful irrigation consulting business in the Hawaiian Islands. Ron Yoder came to ARS in Grand Junction in early 1984. In 1987 he returned with the group to Fort Collins to complete coursework toward his PhD, and remained with the group until 1989. Kruse retired in 1993, and remained a Collaborator of the group for about a decade. He continues to live in Fort Collins, and contributed greatly to preparations for the Centennial celebration of this research group. Yoder is currently the Chairman of the Biological Systems Engineering Department,

Dan Champion, Soil Chemist

Dennis C. Kincaid, Ag Engineer

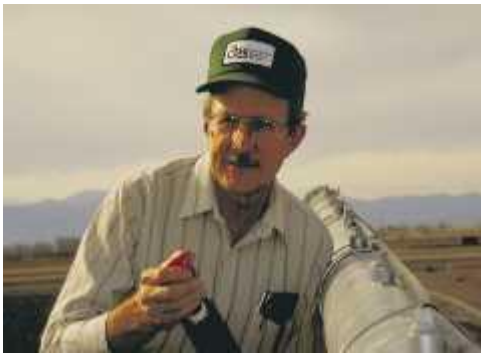
University of Nebraska, Lincoln, and past president of the American Society of Agricultural and Biological Engineers, one of three presidents of the society who were once associated with WMRU.

Ron Yoder. 2007

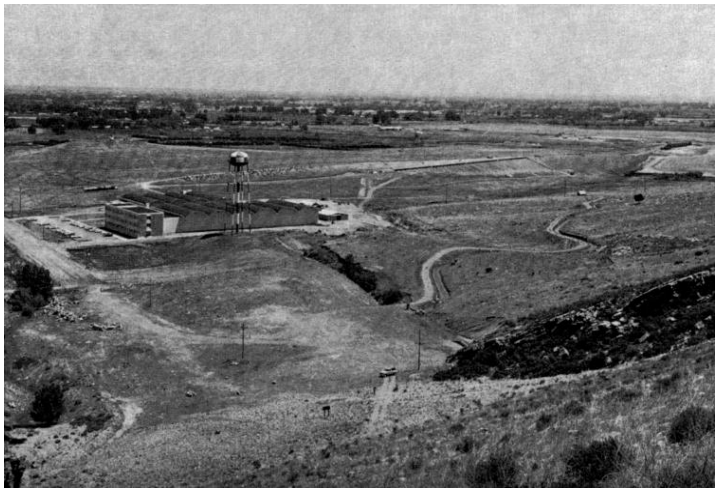
Another ARS engineer, Royal H. Brooks, transferred to Fort Collins in 1957 from the US Salinity Laboratory at Riverside, CA, so that he could enroll in graduate school. During his pursuit of both MS and PhD at Colorado A&M under professor Arthur Corey, he and Corey developed some of the most widely used theories describing water movement in moist soils, which are commonly called the *Brooks and Corey* equations.

Roy Brooks & Art Corey, 1973

Brooks left Fort Collins for Oregon State University in 1967 and another Texan, Harold R. Duke, who had come to Colorado State in 1963 for graduate school, joined the USDA Irrigation and Drainage Unit to fill Brooks' slot in the area of drainage research. Duke soon began work on his PhD, also under Corey, studying water flow in the partially saturated region above agricultural drains, and moved into studies of pollution prevention from the cattle feedlots that are so prevalent in the Great Plains. When Duke began with ARS, he was assigned a former US Forest Service technician named Roy W. Hansen, who continued to support the group until his retirement in 1974. Hansen also assisted with mountain meadow ET studies in South Park and spent one summer at the USBR Seedskadee Development Farm in southwestern Wyoming on a joint ARS-USBR project.



Harold R. Duke, Ag Engineer, 1992

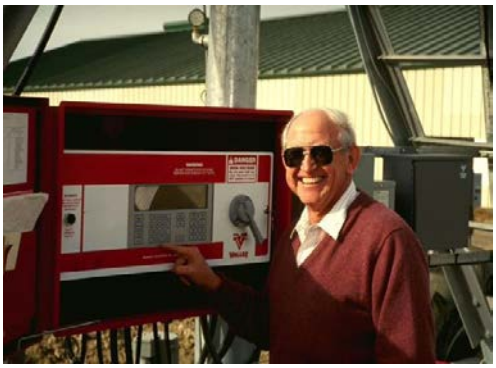


CSU Engineering Research Center, 1963

In 1963, what was by then called Colorado State University completed construction of the Engineering Research Center, located on the Foothills Campus beneath Soldier Canyon dam on the Colorado - Big Thompson project's Horsetooth Reservoir, west of Fort Collins. This new lab featured a high flow rate, high head water supply from the reservoir

directly into research facilities in the laboratory. Among those who relocated with the Civil Engineering Department to that facility were Brooks and Kruse, along with Professor Art Corey's laboratory and graduate students. ERC was to be the primary home of the ARS Irrigation and Drainage Unit until 1980.

A year after Duke joined ARS, a Nebraskan by the name Dale F. Heermann, who had begun graduate school at CSU the year before Duke arrived, left the faculty of CSU to join ARS, although in a different research unit than that of Haise. Heermann started just as a new contraption called a "center pivot" began to catch hold among would-be irrigators in the Great Plains, particularly in those areas where soils were too sandy for practical furrow irrigation. Heermann recognized the potential of these giant machines, and became a pioneer in studying their hydraulic behavior as well as their use to more effectively manage water. He began to develop computer programs to calculate water flows and pressure distribution within these systems. To assist with the routine coding, the unit hired Paul Williams, a mathematician and programmer, who served in that capacity for about a decade beginning in about 1975.



Dale F. Heermann, Ag Engineer, 1992

Adrian W. Thomas (f) and E. Gordon Kruse(r) set field equipment, ca 1970

The Southeast Area of ARS sent a promising young engineer named Adrian W. Thomas to Fort Collins in 1969 to pursue his PhD. He conducted his research in the emerging area of drip irrigation. Thomas completed his PhD in 1972, with Kruse as his major professor and Duke, finishing his own PhD at the same time, as a committee member. Thomas went back to the Southeast to Tifton, GA, and finished his career as Research Leader of the Watkinsville, GA research unit.

By the early 1970's, Heermann and Duke were working as a team, investigating appropriate management strategies for these center pivot irrigation systems in order to maximize crop production while minimizing over irrigation and its attendant potential for water pollution. In 1972, they hired a CU student for summer work on a commercial farm at Crook, near Sterling, CO. Gerald Buchleiter worked summers until he completed his Civil Engineering degree, then went to the world of consulting.

In about 1977, the national ARS office entered into an agreement with NASA to study the use of satellites to attempt to predict worldwide yields of wheat. With the Soviet Union being one of the world's major wheat producers, and it's government being very secretive, fluctuations in wheat yield in the Soviet Union had tremendous and unpredictable impact on the U.S. farm economy. A team of ARS scientists from throughout the Great Plains was set up to establish test

plots on commercial wheat fields ranging from North Dakota through Central Oklahoma and the Texas Panhandle. Heermann, Duke and his technician Mike Blue established a common set of electronic instrumentation and data loggers to be used, devised data collection protocol, and conducted training on instrument installation and servicing for the field teams located in ARS locations at Bushland, TX, Akron, CO, Mandan, ND and Sidney, MT. NASA flew reconnaissance missions to collect remotely sensed data over each field site, and the data were used to develop yield prediction algorithms. To help process these data, Heermann hired a statistician named Kristine M. Stahl. who had previously worked for the US Fish and Wildlife Service at CSU and had served a stint in the Peace Corps in Malaysia. Kris served the unit as both statistician and programmer until her retirement in 2010.

Kristine M. Stahl, Statistician & Programmer

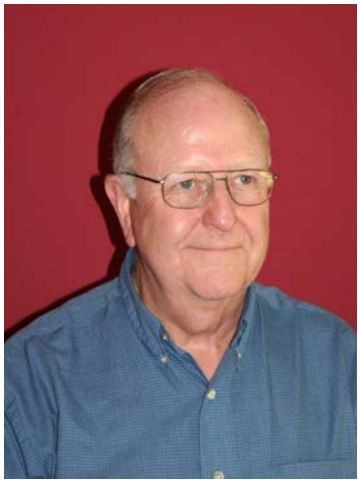
Buchleiter came from consulting to CSU in 1977 to pursue an MS, again working with Heermann and Duke. After finishing his MS in 1979, he joined the CSU staff as a Research Associate supported by ARS. The team began development of computerized controls for center pivots as a means of assisting the electrical generation industry within the High Plains to cope with peak electrical loads in order to avoid "brownouts." They put together a control system on a commercial farm where a personal computer in the farm office monitored local weather as well as the operation of 15 pivots. Whenever the local REA needed to reduce power demand, a signal was sent to the PC, and those pivots best able to do without water were shut off via radio telemetry. This automated, computerized irrigation control is now offered by every pivot manufacturer and opened the way for increasingly more sophisticated irrigation management. Buchleiter joined the Irrigation and Drainage Unit as an ARS research engineer in 1983, and continues as the member of the group with most seniority today. After Roy Hansen retired, the group recruited a young man from North Carolina as engineering technician. Michael C. Blue soon developed an interest in electronics, took a number of correspondence courses, and his job title was eventually changed to electronics technician. He was an instrumental part of the Heermann-Duke-Buchleiter team in development of computer controls for management of center pivot sprinklers, and was part of the team that won national recognition from the US Department of Energy in 1994. Blue passed away in his sleep in 2004, lacking three months having served the agency for 30 years.

Gerald W. Buchleiter, Ag Engineer, ca 1980

Michael C. Blue, Electronics Technician

One of the two or three preeminent soil physicists in the world came to CSU on a sabbatical leave from University of Illinois in 1971. Arnold Klute so enjoyed the mountains that he applied for a position jointly supported by USDA and the Agronomy Department at CSU (The last of what was once a common split appointment between USDA and CSU). When Haise retired in 1974, Klute became RL of the Irrigation and Drainage Unit, and Heermann joined the group shortly thereafter. Klute's work, aided by Heermann's computer programming abilities, centered on modeling hysteretic flows of water in soils resulting from repeated wetting and drying cycles.

Arnold Klute, 1955



Edwin L. Fiscus ca 2010

In 1976, the unit added a Plant Physiologist named Edwin L. Fiscus to study plant water uptake with a goal to develop plants with improved yield under conditions of water stress. Fiscus transferred to an ARS unit at Raleigh, NC in 1989, where he remains today. In 1981, Klute decided to pursue activities that demanded less bureaucratic paperwork, and retired to a mountain home in Estes Park. Heermann was named Research Leader of the Unit at that time.

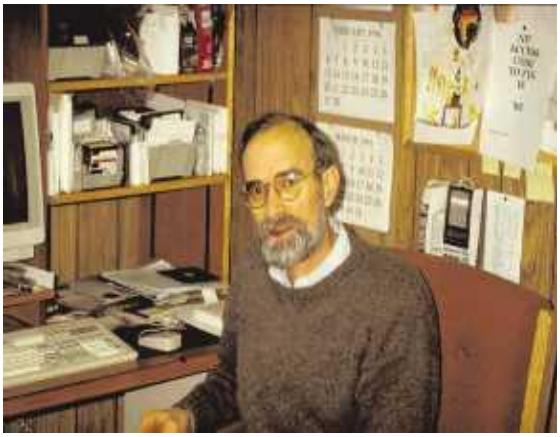
CSU Ag Engineering Research Center

Until 1980, the people who eventually joined together to become the Water Management Unit were scattered around Fort Collins. Kruse and Duke were officed at CSU's Engineering Research Center. Heermann hung his hat in several locations, most recently before merger at a small commercial building on Howes St. Klute was officed in the Plant Science Building on the CSU campus, and others in the ARS Crops Research Lab off Prospect St. In the summer of 1980, Jud Harper of the Agricultural and Chemical Engineering Department arranged for "temporary" facilities at the Agricultural Engineering Research Center to bring the ARS Ag Engineers into closer contact with those of his CSU department. In August 1980, Kruse, Heermann, and Duke moved to the new facility, where they occupied these temporary quarters for twenty three years.

In 1980, a Texas Aggie PhD with training in remote sensing came to Colorado State as an extension irrigation specialist. Walter Bausch served as Extension Specialist until 1984, when he was offered a position with the Irrigation Management Unit to help incorporate remotely sensed information into a computerized irrigation management system. In 1983, during one of several attempts by the Administration to close the ARS station at Sidney, MT, a technician named Ted Bernard moved to Fort Collins to support Klute's program. Bernard worked with Charlie Townsend for a short time after Klute retired, then came to IMU with Bausch in 1985, and continues to serve the Unit today. Bausch used multi-spectral sensing, from sensors mounted on a boom carried above the crop canopy to develop a surrogate for the crop coefficient, based on normalized difference vegetation index, for accurate real-time estimation of crop evapotranspiration. His work has also resulted in techniques for estimating the real-time need for added nitrogen fertilizer. To support remote imaging work by Bausch, the unit arranged for temporary assignment of an experienced imaging engineer from the ARS National Seed Storage Laboratory in Fort Collins. Scott Howarth assisted the unit for about a year before returning to his previous assignment.

Walter Bausch & Ted Bernard, 2011
ARS photo, Peggy Greb

The Fort Collins ARS program was reorganized in 1991, with major changes in both the Hydrology and Sugar Beet units. Roger Smith, an hydraulic engineer internationally known for his work in modeling water infiltration into soils, was on a sabbatical in Germany at the time, but was transferred *in absentia* into the Irrigation Management Unit, renamed at that time as Water Management. Smith continued to work in the area of infiltration, and to improve a water/chemical transport model he had developed, until his retirement in 1999. As a further result of the reorganization, WMRU gained a young PhD mathematician named Richard Miskimins. Miskimins joined ARS in 1983, and has become the principle computer system administrator for WMRU.



Roger E. Smith, Civil Engineer, ca 1995

As part of the reorganization, Edward Schweizer, a preeminent weed scientist, transferred from the Fort Collins Sugar Beet Research Unit to WMRU to provide expertise in agricultural chemical management because the movement of chemicals is so closely related to management of water. Schweizer brought with him a technician who had served him since 1981, Douglass Barlin, who continues to support the Unit with both computer expertise and the weed research field program. Schweitzer retired in 1996 after 35 years service.

Edward E. Schweizer, Weed Scientist

To maintain a broader perspective and bolster the interaction between water and weed control, a young PhD named Lori Wiles was brought to the Unit as a Post Doc in 1991. Dr. Wiles completed her PhD at North Carolina State University and brought expertise in spatial statistics and evaluating the bioeconomics of weeds in cropland ecosystems. In 1994, she transferred to a permanent position with GPSR to work on weed aspects of the GPFARM model, and in 1997 returned to WMRU. Her major efforts have been in computer modeling and field verification of these models. At a 2011 program review of the Water Management Unit, the review team recommended eliminating the weed aspects of the research. As a result, Dr. Wiles has recently changed her focus to that of irrigation management modeler.

Douglass H. Barlin, Biological Tech

Lori J. Wiles, Weed Ecologist

In late 1996, the Unit scientists grew concerned about the apparent lack of scientific input into the rapidly commercializing concept of "Precision Farming." Numerous farmers, in Colorado and elsewhere, were purchasing equipment and software and learning to produce colored maps of the variation of crop yield within their fields. Once the maps were produced, however, there was little guidance as to their further usefulness. Even scientific studies were usually designed to evaluate the correlation between crop yield and a single production variable. WMRU recognized that yield was undoubtedly limited by more than one variable and probably by a different combination of variables in different parts of the field. Thus, the Unit set up a multidisciplinary project in northeastern Colorado with colleagues in other ARS units and at CSU to simultaneously collect data on many parameters, with the hope of developing practical management guidelines for precision

Mary K. Brodahl, Soil Scientist

agriculture. Although each scientist pursued her/his own studies, most work was conducted in the same fields, and all studies contributed toward the overall project. This huge amount of data, and the necessity to use GIS to manipulate data, made it apparent that the unit needed additional support. Mary Brodahl, a Soil Scientist from University of Idaho who had worked for 9 years with Marvin Shaffer on the NLEAP program, came to the unit in 1997 to manage the databases for the project.

In 1987, a young Iranian ag engineer came to WMRU from Arizona to study for a PhD. Hamid J. Farahani completed his PhD under Heermann and Duke. In 1993, he joined ARS as an engineer with another unit, and in 1998 accepted a position with WMRU to support the precision farming project. Farahani worked primarily with Buchleiter to assess soil electrical conductivity and to develop and test variable application technology. He resigned from ARS in 2003 to take an assignment with the International Water Management Institute in Aleppo, Syria where he worked until 2005, then accepted a research position with Clemson University. In 2011 he took a position in the Southeast Regional Technical Center of NRCS in Greensboro, NC.

Hamid J. Farahani, Ag Engineer

Kenan Diker, who completed his PhD in 1998 under Bausch, returned to the US after a stint in the Turkish military and joined WMRU in 2000 as a Post Doc to assist the project with spatial analysis of the mass of data collected through the precision farming project. After his Post Doc position expired, he went to the Colorado State Government in Denver as a GIS specialist, where he remains today.

In December 2001, the Unit hired a preeminent plant physiologist from industry, Dale Shaner, who had been recently named President-Elect of the Weed Science Society of America, to reinforce the weed aspects of the precision farming project. Shaner's studies have concentrated on transport and fate of herbicides under center pivot irrigation, with a goal of variable application to reduce the need for herbicides.

Dale Shaner, Plant Physiologist, 2011 ARS photo, Peggy Greb

The precision farming project continued to be the principle focus of WMRU until 2005. The Unit's main goal was assessing and improving the uniformity of water and N fertilizer application; assessing the distribution of weed seeds and seedlings, and the potential for variable herbicide application; assessing the relation between easily measured soil properties and parameters related to yield; using remote sensing and image analysis technology to determine the spatial need for N fertilizer; and developing technology to convert GIS maps of chemical application requirements into

commands for a variable chemical application system developed cooperatively with industry. A drought in eastern Colorado resulted in the State having to restrict irrigation by well owners in the central South Platte basin in order to supply senior water right holders further downstream. Therefore, one of the two cooperating farmers was forced to stop irrigation, effectively halting research in precision farming at the site.

After two attempts to build new facilities for Water Management and other ARS units in Fort Collins who had been housed in rental space, the Agency was finally able to begin serious design planning in the late 1990s. A three-way cooperative building program between Colorado State University (providing the land), commercial contractors (providing buildings) and USDA

USDA Natural Resources Research Center, Building D, completed 2003

(providing rental money through GSA), allowed launch of a major USDA building project about a half mile south of the CSU campus. The ARS shop and office complexes were the fourth and fifth buildings of the complex, which today houses some 1400 USDA employees. After 23 years in temporary facilities, WMRU moved into this new building in November 2003. At the time of the move, the unit hired a recent agricultural engineering graduate named Paul Irvin to manage the new fabrication shop at the complex.

Paul Irvin, Shop Supervisor

As the population of the eastern Colorado Front Range has grown, so has the competition for water to provide for the growing cities. As a result of greater purchasing power, municipalities have bought irrigated farm land along the foothills for the purpose of diverting some or all the water to urban use. The outcome of the 2005 WMRU program review was to refocus the research of the unit on utilizing a dwindling supply of irrigation water for limited irrigation in order to maintain both the urban population and a viable irrigated agriculture. Heermann began to change the focus of the unit before his retirement in May 2005. Dale Shaner stepped in as interim Research Leader until Heermann's replacement arrived in early

Tom Trout, Ag Engineer & RL.

2006. Heermann passed away in February 2009.

Tom Trout received an MS at CSU in 1975, then served a tour with the University in Pakistan on an international project. He received his PhD in 1979 based on his Pakistani work, and joined ARS at Kimberly, Idaho in 1982. In 1995, he became ARS Research Leader at Parlier, CA where he oversaw design and construction of a new building. After Heermann's retirement, Trout accepted the Research Leader position in Fort Collins. He has directed establishment of the new program in limited irrigation research at the one-time USDA Potato Disease Research Station northeast of Greeley, where WMRU conducted irrigation research from 1979 to 1984.

Limited Irrigation Research Facility (LIRF), photo bef. 1978

The newest member of the scientific staff of WMRU is Louise Comas, a plant physiologist who received her PhD from Penn State and did Post Docs with both Penn State and the ARS unit at University Park. Louise began work in July 2011 and is beginning to develop her research program to provide fundamental information on plant growth and development under deficit irrigation. Initial studies will examine the plasticity of root growth in corn and sunflower and how it is tied to optimal growth and yield under varying levels of deficit irrigation. Kendall DeJonge came to Colorado State after completing his degree in Agricultural Engineering at Iowa State University. As of this writing, he has completed all requirements for his PhD, and is currently serving as an Ag Engineer with the unit.

Kendall DeJonge, Ag Engineer and Louise Comas, Plant Physiologist, 2011

Dorothy “Dottie” Depperschmidt is the sole Administrative Assistant for the unit, having started with the unit while Heermann was Research Leader. Garrett Banks has completed a degree in Environmental Engineering at CSU, and serves as an Engineering Technician for the group. Eight undergraduate students complete the support staff for the summer of 2011.

Rich Miskimins, IT & Dottie Depperschmidt, Administrative Professional

During the first 100 years of the Water Management Research unit in Fort Collins, it has been staffed by 26 Category 1 scientists. Five of those were here on temporary transfer specifically to get an advanced degree. All except six have been engineers, those others being a soil physicist, two plant physiologists and three weed scientists.

Garrett Banks, Engineering Tech

Impact of Water Management Unit Research

As public servants, the employees of the Water Management Unit have long been aware of the public stereotype of the government employee. However, for the past century, this unit has taken great pride in knowing that their efforts have contributed to making US agriculture the most efficient food and fiber production industry in the world. In spite of recent increases in world food prices, today's housewife still pays less (real cost) for food today than at any time since the Great Depression (Finance and Development, v48, 2011). When this research unit began in 1911, more than 30 percent of the US population lived and worked on the farm. Today less than 2 percent do so. By comparison, farm population in India is still more than 65 percent of the country's total, but declining rapidly. A Congressional Budget Office report of a couple decades ago estimated that each $1.00 spent on agricultural research returned $7.00 to the American consumer – a return that would please any investor then or now.

One of the most important impacts of this unit has been its role in developing young professionals from all corners of the world. Although records are incomplete, we estimate that at least 300 college students have received support from part-time work with the Water Management Unit. The professional staff of the Unit have served on Graduate Committees, as member or major adviser, more than 280 times. At least five scientists associated with the Unit have gone on to serve as Presidents of major professional societies. Three have become States Engineer of Colorado. More than a dozen have become Fellows of their respective professional societies, and untold numbers have received regional, national, or international awards for their professional accomplishments. Former students have come from every populated continent, and most have gone back to become high level technical people in their own countries.

The importance of the synergy between the Agricultural College in Fort Collins and the USDA irrigation research program here cannot be overemphasized. Since 1887, the Federal Hatch Act has provided USDA money to help support State Experiment Stations, including at Fort Collins. In turn, USDA's irrigation research program has been provided office and research facilities for most of its staff on the campus of what is now Colorado State University for the entire century of its existence – without charge for many years. WMRU staff have had faculty privileges,

including tuition waiver in the early years, and access to University facilities and services. In exchange, we have occasionally taught graduate level courses and have provided countless hours of service to students at no cost to the University.

Specific accomplishments by the Unit and their impact include:

- **The *duty of water*.** Little was known at the beginning of the 20th century about how much water was needed to produce a crop, nor about how much natural precipitation needed to be supplemented by irrigation. Studies by this group provided a basis for determining the required capacity of irrigation systems and equitable allocation of water in order to produce crops in the arid west.
- **Canal seepage and evaporation.** Studies of Colorado's canals and field ditches documented the extent to which water was lost before reaching the field and developed methods of reducing those losses. Studies in USDA facilities determined how much water was lost to direct evaporation from the many surface reservoirs that were built in the latter part of the 19th century.
- **Design of interceptor drains.** Canal seepage and percolation below the root zone created problems of high water tables, particularly in the low lying areas below these facilities. New design procedures resulted in vast installations of single drain lines to intercept this groundwater before it could cause down-slope problems.
- **Design of water wells.** Results of early studies to improve the design of water wells, and to incorporate gravel packs to stabilize the surrounding aquifer materials greatly extended the life of wells. These results were incorporated into a national ASAE Standard in the 1960s.
- **Parshall Flume.** Parshall's flow measurement device allowed accurate measurement of water delivery even under conditions where little drop in water surface through the measuring device was available. The flume design also tended to be self-cleaning, preventing buildup of silt from decreasing accuracy. These flumes were adapted worldwide, and are required by law in some places for certain measurements. (US Patent, Ralph L. Parshall, “Venturi-Flume Water-Stage Recorder Instrument” 30 May 1932)
- **Vortex tube sand trap.** A major source of canal sedimentation problems was averted by the development of a diagonal slot in the bottom of a canal into which sediment would fall, be kept suspended by swirling motion, and carried to the side of the canal to be discharged back into the river source.
- **Jensen-Haise evapotranspiration equation.** Early methods of estimating crop water use based upon local climate made use of only average air temperature. Such methods provided useful estimates for seasonal water use and were long the standard for project design capacity, yet lacked the ability to react to short term fluctuations in water use. Adding solar radiation to the computation greatly increased the short term accuracy and made such computations useful for making irrigation decisions based on nearby meteorological measurements.
- **High mountain meadow water use.** As Front Range populations grew, cities began to explore sources for additional water supplies. In order to be allowed to 'dry up' irrigated areas and divert the water to the city, studies were required to verify the difference in the

amount of water used under irrigation and that used after irrigation ceased. That difference was then allowed to be purchased from the landowner and stored for municipal use. Denver Water, in particular, utilized the results of these studies to procure large supplies of additional water.

- **Surface irrigation automation.** Numerous devices were developed that provided reliable automated control of surface irrigation systems, both from open ditches and from moveable pipe. Several of these devices were adapted internationally, particularly in New Zealand. A major obstacle to adoption in the US was a lack of a single source for 'turnkey' installation as farmers had come to expect from dealers for other types of farm equipment. Rapid deployment of center pivot and similar moving sprinkler irrigation systems, which were inherently adaptable to automation, soon overshadowed the need for surface automation on large scale farms. (US Patents, Howard R. Haise & E Gordon Kruse, “Remote Control Irrigation System” 23 May 1967; Clayton H. Gibson & David A. Young, “Retrofit Device for Alfalfa Valve” 13 Oct 1987)
- **Drainage and porous media flow theories.** The Brooks and Corey equations provided a methodology by which unique characteristics of a given soil could be incorporated into computational methodology. These methods have been used to improve the design of agricultural drains, to develop methods to manage deep percolation of water and fertilizers below the crop root zone, and to develop remediation techniques for contaminants moving to the water table.
- **Irrigation scheduling for center pivots.** USDA engineers at Kimberly, Idaho developed the first sophisticated methodology for determining when to apply irrigation water based on locally measured meteorological parameters. The Fort Collins unit adapted these methods to take advantage of the precise water control and unique characteristics of the center pivot system to develop an irrigation scheduling program specifically for these systems. This work and outreach efforts of the Fort Collins group were the basis of a US Department of Energy Award in 1994.
- **Salinity management under irrigation.** Results from intensive field studies in the Grand Valley to determine canal seepage, tailwater runoff, and in-field percolation of excess water were used to develop water management techniques to reduce the return of salts to the Colorado River. The US Bureau of Reclamation and Natural Resource Conservation Service incorporated these study results to implement irrigation system improvements in the Valley in response to a Court order to improve Colorado River water quality below the Grand Valley.
- **Surge irrigation management.** Surge irrigation is a concept used by farmers for decades, whereby furrows would be irrigated until the water advance slowed, then moved to a new area for a time; coming back to finish the first set of furrows later. The result was that water could be advanced to the end in less total time than if irrigation had been continuous. Utah State University engineers formalized the process in the 1980s, and in fact patented it in 1985. WMRU and CSU engineers conducted tests on different soils, slopes and furrow lengths and developed management criteria. Several irrigation companies developed valves to semi-automate irrigation by the surge process, and it was widely adopted, particularly in the southern High Plains. Continually declining water supplies in that area have resulted in conversion of much this formerly surface irrigated

land to low volume, self-propelled sprinklers.

- **Nitrogen leaching under center pivots.** WMRU studies on farmers' fields demonstrated the value of improved water management to both water conservation and reducing leaching of mobile nitrate fertilizer. On sandy soils, use of the WMRU center pivot irrigation scheduling program reduced total water application by 2 inches and nitrate nitrogen leaching by 31 pounds per acre.
- **Water and energy management system (WEMS)**. When electrical energy generation capacity became critical in the late 1970s, WMRU developed the WEMS to incorporate irrigation scheduling technology into an automated, telemetry control system to automatically reduce irrigation in times of high electrical demand, while shutting off only those center pivot systems that had sufficient soil water to withstand short interruption without reducing crop yield. The engineers worked directly with the largest center pivot manufacturer to bring that computerized system to market. Today, every manufacturer provides a similar computerized pivot control system allowing remote operation and monitoring of its pivots.
- **Center pivot evaluation and modeling.** Heermann's original hydraulic equations for the center pivot were incorporated into a computer program (CPED) by WMRU. This program provides a complete analysis of system operation, application depth, pressure distribution, and uniformity as the system operates over existing terrain in the individual field. Today, CPED is part of the official 'toolbox' of the Natural Resource Conservation Service, and is used to evaluate NRCS supported improvements to center pivots to determine compliance with the Environmental Quality Incentives Program (EQIP).
- **Remote sensing for irrigation scheduling.** The reflectance-based crop coefficient (K_{cr}) responds to actual crop growth, typically different from year-to-year due to climate effects, soil moisture and management, whereas traditional crop coefficients represent average conditions. Pilot studies in Spain, Portugal, and Italy (2003-2005) provided K_{cr} maps based on the NDVI from satellite images in near real-time to demonstrate improvements in farm and irrigation advisory services (IAS) day-to-day operations. Cost analysis indicated that the space-assisted IAS was approximately 30% less expensive per ha than conventional IAS. Scientists at Utah State University and the Arid Land Agricultural Research Center (Maricopa, AZ) are using the technique to develop reflectance based crop coefficients for other crops for irrigation scheduling.
- **Remote sensing for nitrogen management.** The nitrogen reflectance index (NRI) developed by Bausch provides rapid assessment of plant N sufficiency as well as its spatial variability within a field, enabling site- and time-specific N management decisions which reduce costs and potential pollution by applying N only when and where needed in a given field. Nitrogen applied in three site years was reduced by 35, 100, and 148 lb N/ac compared to the farmers' practice in the remainder of the field which resulted in nitrogen cost savings of $6.60, $27.70, and $41.00/ac, respectively. Grain yield was comparable for the remote sensed management scheme and the farmer practice.
- **Precision farming.** Although this project was terminated by state mandated restriction on pumping, the preliminary results demonstrated that even in fields that appear quite uniform from the ground, virtually every parameter measured showed large variability over relatively short distances. Soil electrical conductivity, indicative of soil texture, was

correlated with most measured parameters, including fertility, weed populations, insect populations and crop yield. Even though the center pivots applied water quite uniformly, natural precipitation and farmer's management decisions resulted in a large variation of total water application across each field over the growing season, which in itself impacted fertilizer availability and yield. Variable application of both water and fertilizers based on remotely sensed data demonstrated that significant savings could be achieved for both by using these near real-time techniques.

Current Water Management Research Unit Staff (September 2011)

Front Row: James Haley, Brenna Mefford, Liam Cummins, Robyn Bartling, Jordan Varble,
Seated: Garrett Banks, Louise Comas, Dottie Depperschmidt, Mary Brodahl, Lori Wiles, Amanda McKay
Standing: Ted Bernard, Kendall DeJonge, Tom Trout, Dale Shaner, Doug Barlin, Gerald Buchleiter, Dave Remucal, Walter Bausch, Richard Miskimins
Not pictured: Paul Irvin, Grace Lloyd, Caitlin Condon

Historical Personnel

We believe that the list all those presently be called Category 1 scientists who have served the Unit over the past century, as well as the Category 3 Support Scientists, is nearly complete. However, the equally important support help is not so complete. Limited availability of official personnel records leaves us at the mercy of aging memories to try to reconstruct a list of those personnel. We have not attempted to assign dates of employment to these folks, but they are listed in approximate chronological order. There is no question that this list is incomplete; we apologize to those who are not included:

Category 1 Scientists:

Victor Mann Cone – 1911 to 1918
Ralph Leroy Parshall – 1913 to 1959
Carl H. Rohwer – 1914 to 1956
A. R. "Robbie" Robinson – 1951 to 1963
Howard R. Haise – 1954 to 1974
R. William Nelson – 1956 to 1959 (TDY)
E. Gordon Kruse – 1957 to 1993
Royal H. Brooks – 1957 to 1967 (TDY)
Marvin E. Jensen – 1959 to 1964 (TDY)
Harold R. Duke – 1967 to 2002
Dale F. Heerman – 1968 to 2005
Adrian W. Thomas – 1969 to 1972 (TDY)
Arnold Klute – 1971 to 1981
Dennis C. Kincaid – 1976 to 1979
Edwin L. Fiscus – 1976 to 1989
Gerald W. Buchleiter – 1983 –
Walter C. Bausch – 1984 –
Ronald E. Yoder – 1984 to 1989 (TDY)
Scott Howarth – ca 1983-1984
Roger E. Smith – 1991 to 1999
Edward E. Schweizer – 1991 to 1996
Lori J. Wiles – 1991 to 1994, 1997 –
Hamid Jalali-Farahani – 1998 to 2003
Dale Shaner – 2001 –
Thomas Trout – 2006 –
Louise Comas – 2011 –

Administrative-Professional:

Edith Stanton Sadar *(lost job to ARS nepotism rules when she married E. Gordon Kruse)*
Judy Cobb
LuAnn Lee
DeeAnn Holbein
Fran Lyons
Judith Hopper
Edith Moore
Deborah Price
Lorraine Stephens
Irene Polnau
Rose Mulder
Louise Dalton
Alice Arnold
Mia Dailey
Nora Kohuth
Mary van Cleve
Maxine McCauley
Carol Bernard
Dorothy "Dotty" Depperschmidt

Technicians/Support Scientists:

Roy W. Hansen
Meredith L. "Bud" Payne
Phil Whitney - died in Vietnam
Michael C. Blue
Michael Raney
John Reagan
Paul F. Williams
Daniel Champion
David Young
Martha "Marti" Cary Kincaid

Clayton Gibson
Gordon Fischbacher
Dan Cuevas
Beverly Motz
Linda Gray
Paul F. Williams
Kristine M. Stahl
Stanley Wullschlegger
Theodore “Ted” Bernard
Daryl Carr
Hubert Lagae
Mary van Cleve
Gregory Larsen
Richard Miskimins
Douglass H. Barlin
Christine Andre
Mark R. Collins
Rob Mason
Mary K. Brodahl
Brian Ebel
Kenan Diker
Paul Irvin
Joven DeHerrera
Erik Wardle
Dean Santistevan
Kendall DeJonge
Garrett Banks

Visiting Scientists/Sabbaticals:
Dr. Ion M. Nicolaescu, Romanian Professor of Irrigation Engr.
Mr. Graham Harrington, Irrigation Ministry, New Zealand
Dr. Luis Gurovich, Catholic University of Chile, Santiago
Dr. Ted Loudon, Michigan State University
Dr. Earl Stegman, North Dakota State University
Dr. Eugene Rochester, Auburn University
Dr. Rosario Camiera, Technical University of Lisbon, Portugal
Mr. Antonio Serafim, Technical University of Lisbon, Portugal
Dr. Paulo Luz, Ministry of Agriculture, Lisbon, Portugal
Dr. Ramon Lopez-Urrea, Albacete, Spain

Graduate Student Committees Served by ARS Irrigation Staff (Partial List)

Year	Degree	Dept	Student	ARS Committee Member (s)
1949	MS		Gilbert L. Corey	Rohwer
1951	MS		Jack S. Peterson	Rohwer
1952	MS		Frank Leatherwood	Rohwer
1954	MS		John Lockman	Rohwer
1955	MS	AE	Allen D. Halderman	*Robinson
1956	MS	AE	Jack Keller	*Robinson
1961	MS	AE	Charles W. Huntley	Jensen
1962	MS	AE	Cornelis des Bouvrie	Robinson
1964	MS	AE	Dale Heermann	Kruse
	PhD	AE	E. Gordon Kruse	Robinson
	PhD	CE	Jeris Danielson	Kruse
1966	MS	AE	Richard J. Wenstrom	Kruse, Heermann
	MS	AE	Robert W. Saulmon	*Kruse
	MS	AE	Allen R. Rider	Kruse, Haise

	MS	AE	Frank J. Dragoun	*Kruse
	MS	AE	Terry Gowin	*Heermann
1967	MS	AE	Donald L. Reddell	Duke
	MS	AE	Thomas A. Reid	*Brooks
	MS	AE	Larry F. Land	Duke
1968	MS		Jim Mahar	Duke
	MS	AE	James R. Gilley	Heermann, Kruse
	MS	AE	Syed Navaid Nasri	Heermann
	MS	AE	Dennis C. Kincaid	*Kruse
	PhD	AE	Nikolas. F. White	Duke
	PhD	AE	Dale Heermann	Kruse
1969	MS	Earth Sci	Robert Stollar	Duke
	MS	CE	Robert Bibby	Duke
	MS	CE	Harold Simpson	Duke
	MS	AE	Douglas T. Sovern	*Kruse
	PhD	AE	Martin J. Payne	Kruse
	PhD	AE	Gale A. Holloway	*Heermann, Kruse
	PhD	CE	Donald Lee Reddell	Duke
1970	PhD	AE	Dennis C. Kincaid	*Kruse, Heermann
	PhD	AE	Donald L. Reddell	Duke
1971	MS	AE	Gerald M Davisson	Heermann
	MS	AE	Habte Mariam Neghassi	Heermann
	PhD	AE	Warren E. Hedstrom	Duke
	PhD	Nat Res	Harold Stepphun	Duke
	PhD	CE	David Sapik	Duke
1972	MS	AE	Luis E. Quintero	*Heermann, Haise
	PhD	AE	Brij Mohan Sahni	Heermann, Klute
	PhD	AE	Harold R. Duke	Klute
	PhD	AE	Adrian W. Thomas	*Kruse, Duke
	PhD	AE	John W. Addink	Heermann, Kruse, Smith
1973	MS	AE	Robert L. Chandler	Heermann
	PhD	AE	G. Morgan Powell	*Jensen
	PhD		James Foster	Duke
1974	MS	Agron	Shaul Manor	*Klute, Duke, Haise
	PhD	AE	Habte Mariam Neghassi	*Heermann
	PhD	AE	Mahmood Shariatmadar	Klute, Duke
	PhD	Agron	Jaimer Navas Alvarad	Heermann
1975	MS	AE	Jorge S.A. Torres	Duke
	MS	AE	Henry O. Fapohunda	*Heermann
	MS	Earth Sci	Edmund Joe Schneider	Kruse
	MS	CE	William C. Hill	Kruse
	PhD	AE	Mahmood S. Taleghani	Duke
1976	MS	AE	Leonard J. Ring	Heermann
	PhD	AE	Nazar Ali Sabti	Duke

	PhD	AE	James E. Ayars	Klute, Duke
1977	PhD	AE	Blaine R. Hanson	Duke
	PhD	AE	Jose L. Trava	*Heermann
	PhD	Agron	Arno Sighart Desbese	Heermann
	PhD	CE	Nestor Ortiz	Duke
1978	MS	CE	Lyle Davis	Duke
	MS	CE	Frederick Lux III	Kruse
1979	MS	AE	Bradley J. Young	*Heermann, Duke
	MS	AE	Gerald W. Buchleiter	*Heermann, Duke
	MS	AE	Michael John Moodie	Heermann
	MS	CE	Steven G. Buchberger	Smith
	PhD	AE	Wiboon Boonyatharoku	Kruse
1980	MS	CE	Paul E. Clopper	*Smith
	MS	CE	Robert J. Montgomery	*Smith
	PhD	AE	M. Mahmoodian-Shooshtari	Duke, Heermann, Klute
	PhD	AE	Mohan Reddy (Junna)	Kruse
	PhD	AE	Blanor Loureiro	Duke
1981	MS	AE	Charles W. Binder	Duke
	MS	AE	Robert W. Beccard	*Heermann, Duke
	MS	AE	Martin A. Sailus	Duke
	PhD	AE	Ronald L. Elliott	Heermann
1982	PhD	AE	John E. Gilley	Smith
	PhD	AE	Shlomo Pleban	*Heermann, Duke
	PhD	AE	Ezatollah Raeissi-Ar	Heermann, Kruse
1983	MS	AE	Peter Livingston	Duke
	MS		Steve Scheitlin	Duke
	MS	AE	Dov Shacham	Heermann
	MS	AE	David J. Stieb	*Duke
	PhD	AE	Donald R. Frevert	Kruse
	PhD	AE	Norman L. Klocke	*Heermann, Duke, Klute
	MS	CE	Martin Aboitiz-Uriar	Heermann
1984	MS	AE	Douglas L. Smith	*Duke
	MS	AE	Don Homan	*Heermann
	MS	AE	David B. Fisher	Duke
	MS	AE	Maria J. Jensen	*Heermann, Duke
	MS	CE	Pascual Luis Maria Fernandez	Bausch
	MS	AE	Christopher M.U. Neale	*Bausch, Duke
	MS	CE	Jorge Ramirez	Bausch
	PhD	AE	Muhammad S.Shafique	Kruse
	PhD	AE	Ali A. Ikhneifir	Heermann, Klute
	PhD	AE	Dean E. Eisenhauer	*Heermann, Duke, Klute
	PhD	AE	Ali M. Adeeb	Duke, Heermann, Klute
	PhD	AE	Derrel Martin	*Heermann, Duke
	PhD	AE	Walter L. Trimmer	*Duke, Heermann

	PhD	AE	Forrest T. Izuno	*Duke, Klute
	PhD	CE	Roger Stillwater	Duke
	PhD	CE	Mark Grismer	Duke
1985	MS	AE	Benjamin Doerge	*Duke
	MS	AE	Bruce D. Wright	*Bausch
	MS	AE	John Raymond Hervé	Bausch
	MS	AE	Charles F. Mayzlik	Bausch
	PhD	Agron	Clement Pearson Mzembe	Bausch
	PhD	AE	Paul Lynn Wattenburg	Kruse
	PhD	CD	R. Lee Payton, Jr.	Smith
1986	MS	AE	Johnathan B. Harcum	Duke
	MS	AE	Dick Wolfe	*Duke
	MS	AE	Peter G. McCornick	Klute, Duke
	MS	AE	Ramanathan Sri Ranjan	Duke
	PhD	AE	Steven E. Hinkle	*Heermann, Duke, Klute
	PhD	AE	Gerald W. Buchleiter	*Heermann, Duke
1987	MS	AE	Frederick L. Charles	*Bausch, Kruse
	MS	AE	Jefferey A. Westendorp	Duke
	MS	CE	Jill Renae Biesma Keiner	Smith
	PhD	AE	Christopher M.U. Neale	*Bausch, Heermann, Duke
	PhD	AE	Shahid Ahmad	*Heermann, Bausch
	PhD	AE	Robert Ali Mohammed	Bausch
	PhD	AE	Aws Alouini	Heermann
	PhD	AE	Choudhiry Amiruddin Khan	Kruse
	PhD	CE	Saleh A. Alhassoun	Bausch
1988	MS	AE	Numan Rashid Mizyed	*Kruse
	PhD	AE	Behzad Izadi	*Heermann, Duke, Klute
	PhD	GSMS	Ki Hee Ryu	*Kruse
	PhD	AE	Abdelaziz Eddebbarh	Heermann, Klute
	PhD	AE	William E. Spurgeon	*Duke
	PhD	AE	Todd P. Trooien	*Heermann, Bausch
	PhD	CE	Frederick Nine-fang Chou	Heermann
	PhD	AE	Mariano Guardo	Kruse
	PhD		Roger Stillwater	*Kruse, Duke
	PhD	AE	Ronald E. Yoder	Duke, Klute, Kruse
1989	MS		Ramon Chacon	Duke
	MS	CE	Fred Ogden	Duke
	MS	AE	Luis Alberto Ortiz D	*Heermann, Buchleiter
	MS	AE/CE	Donald L. Baker	Bausch, Kruse
	PhD	AE	Ramanathan Sri Ranjan	Duke
	PhD	CE	Leslie Bach	Duke
1990	MS	AE	Delbert Smith	*Duke
	MS	AE	Lutfi Eyuboglu	*Duke, Kruse
	MS	GSMS	Ali Firouzi	Bausch

	PhD	AE	Jonathan B. Harcum	Duke
	PhD	AE	Rose Mary Seymour	Klute, Kruse
	PhD	AE	Mathias Fru Fonteh	Kruse
1991	MS	AE	Hiromitsu Tada	Duke
	MS	AE	Joseph R. Pollara	Kruse
	MS	CE	Taha B.M.J. Ouarda	Heermann
	PhD	CE	Luis Guillermo Cadavid	Smith
	PhD	AE	Hamid Jalali Farahani	*Heermann, *Duke
	PhD	CE	Farida Elhessy	Kruse, Jensen
	PhD	AE	Bassam Hasbini	*Buchleiter, Duke
1992	MS	AE	Ahmet Erkan	Duke
	MS	AE	Faisal I. Zeineldin	Heermann
	PhD	CD	Abdulmohsen A. Alsahaikh	Jensen
	PhD	AE	Liberato L. Piczon	Kruse, Jensen
1993	MS	AE	Kevin D. Lusk	Kruse, Duke, Bausch
	MS	AE	Kirk R. Thompson	Duke
	MS	AE	Bernard T. Nolan	Smith
	MS	Hort	David P. Staats	Kruse
	PhD	CE	Flavio G. De Albuquerque	Jensen
	PhD	AE	Armando C. Parente	Heermann
	PhD	AE	Muhammad Ashraf	Duke
	PhD		Doug Hansen	Duke
	PhD	AE	Muhammad Iqbal	Kruse
	PhD	CD	Faraj Amine Elawar	Jensen
1994	MS	Ag Econ	Steven Shawn Vickner	Duke
	MS	AE	Mohammed Al-Saud	Duke
	PhD	AE	Aidan Senzanje	Heermann, Duke
	PhD	AE	David Gene Wagner	Jensen
	PhD	AE	Moshrik R. Hamdi	Duke
	PhD	AE	Clyde W. Fraisse	*Heermann
1995	MS	CE	Mohamed Al-Sahd	Duke
	MS	AE	Andrew D. Rockwell	Duke
1996	MS	Hort	David Hillock	Duke
	MS	AE	Monte A. Dickson	*Bausch , Schweizer
	MS	Agron	James Kenall Boyd	Duke
	MS	CE	Jennifer Payne Zung	*Smith
	MS	Agron	Edmund Joseph Barry	Bausch
	PhD	AE	Judith Anne Billica	Duke
	PhD	Agron	Zhang Yousheng	*Smith
1997	MS	CBE	Charles Newcomb	Duke
	MS	CE	Margaret Terese Herzog	Heermann
	MS	GSMS	Kevin Douglas Reid	Smith
1998	MS	AE	Robert W. Jordan	*Duke, Heermann
	MS	Hort	Scott Dunn	Duke

	MS	AE	Ty W. Morton	*Buchleiter, Wiles
	PhD	AE	Faisal Ibrahim Zeinedeln	Duke
	PhD	AE	Kenan Diker	*Bausch
	PhD	AE	Rolando Gaal Vadas	Jensen, Heermann
	PhD	AE	Khalid Ali Al-Gaadi	Bausch
	PhD	Agron	C.J. Iremonger	*Duke
	PhD	CE	Doug Hansen	Duke
1999	PhD	AE	Mohammed I. Al-Saud	Duke
	PhD	Agron	Ronald E. Godin	Duke
2000	PhD	Bio Ag Sci	Dawn Y Wyse-Pester	Wiles
	PhD	AE	Sylvana Della Manna	*Heermann
2001	MS	AE	Tyler D. Schleicher	*Bausch
	PhD	AE	Stanley C. Best	*Duke, Heermann, Buchleiter
2002	MS	CE	Rosalia Rojas-Sanchez	*Smith
	MS	CE	Jeremiah Jason Szynskie	Bausch
	MS	Agron	David Keith Wright	Bausch
2003	MS	CE	Molly C. McCutcheon-Watkins	*Bausch, Buchleiter
	PhD	Agron	Kim L. Fleming	Bausch, Heermann
	PhD	AE	Cagatay Tanriverdi	*Bausch
2004	PhD	Agron	Colleen Heather Green	*Smith
2007	MS	AE	Karl J. Mauch	Bausch
2011	MS	CE	Jordan Levi Varble	Trout
	PhD	Agron	Hamdan S. S. Al-Wahaibi	Trout

***** - Thesis Adviser

Dept – Academic Department

AE - Agricultural Engineering, later Agricultural and Chemical Engineering
Ag Econ – Agricultural Economics, later Agricultural and Natural Resource Economics
Agron – Agronomy, Soil and Crop Science
Bio Ag Sci – Entomology, Plant Physiology, later BioAg Science and Pest Management
CE – Civil Engineering
Earth Sci – Geology, later Earth Science
Hort – Horticulture
Blank – record is incomplete