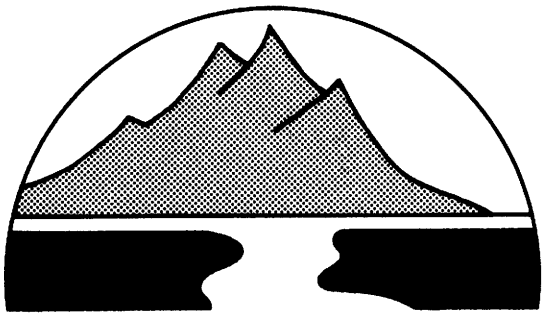
Report No. G943–01

FISCAL YEAR 1984 PROGRAM REPORT

WYOMING WATER RESEARCH CENTER



UNIVERSITY OF WYOMING
Laramie , Wyoming

Report No.
G943-01

FISCAL YEAR 1984 PROGRAM REPORT

Grant No. 14-08-0001-G943

for

U.S. Department of the Interior
Geological Survey

by

Wyoming Water Research Center
University of Wyoming
Laramie, Wyoming 82071

Robert W. Brocksen, Director

September 1985

"The research on which this report is based was financed in part by the United States Department of the Interior, Geological Survey, through the Wyoming Water Research Center."

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ABSTRACT

Five projects were funded under the FY 1984 program which covered topic areas in water quality problems in organic contaminant transport between groundwater and surface waters, prediction of trout density in montane areas, prediction of runoff from snowcover in montane areas using satellite imagery for water management, soil compaction in furrow irrigation to improve irrigation efficiency for agriculture and estimation of secondary costs associated with water development. Information transfer was done principally through a symposium on Wyoming water problems, extension activities, mailings on available publications through a newsletter and participation at several meetings held by groups in the State of Wyoming on water issues.

A field study on the movement of organic contaminants through the groundwater to surface streams from a wood-treating facility indicated that oily seeps occur into the surface stream. Soil column experiments have shown that organic contaminants as emulsions move faster through a soil column than a dissolved single compound.

Multiple regression models (three) were developed to predict trout abundance in high mountain streams in Wyoming using geomorphic and instream habitat parameters. Correlations between predicted and actual trout abundance for the three models developed were 0.80, 0.75 and 0.32.

Correlations between snowcover and runoff using satellite imagery for drainage basins in Wyoming were developed to provide a basis for estimating expected runoff from snowcover using the latest satellite data available each year. Dates for beginning, peak and end of spring snowmelt can be predicted.

A field evaluation of compaction effort for different furrow shapes for hydraulic and infiltration characteristics to improve irrigation efficiency was performed. Furrow shape and compactive effort are both important factors to improved irrigation efficiency and traditional methods of analyzing furrow irrigation were found unsatisfactory because of furrow shape.

Two proposed water development projects in Wyoming were used to identify and quantify secondary costs and benefits of economic, demographic and public sector impacts through the use of a computerized impact assessment model. Both projects produced a net public sector surplus at the local level, but deficits for the State overall.

WATER PROBLEMS AND ISSUES OF WYOMING

Wyoming's heritage stems from her abundance of natural resources. Vast areas of range and pastureland interspersed with fertile, irrigable stream valleys have enabled the agricultural and livestock industry to become a major driving force of the State's economy. The recreation and tourism industry thrives in Wyoming as visitors come to share our wealth of scenic beauty. Beneath the land surface lies such mineral resources as coal, oil and gas, uranium, oil shale, trona, gypsum, and iron ore. Their abundance has enabled Wyoming to become a national leader in mineral production.

Water is the key natural resource controlling the development of each of these industries. As the saying goes, "in Wyoming, water is life". The rancher could not survive our semi-arid climate without water for livestock and irrigation. Without our streams, lakes and reservoirs, the quality of the recreationists' experience could be diminished. If the mineral industry is to continue to provide a major source of income in the State, water will be required. As our cities and towns continue to grow, adequate supplies of good quality water must be available.

Water availability and allocation for agriculture, mineral extraction, industrial development, recreation, and municipal consumption continue to be the center of water related problems in Wyoming. The development of new water resources through impoundment, while complying with existing interstate water compacts, is a challenge in planning and implementation. Once additional surface and groundwater supplies are

available, the equitable distribution, conservation and maintenance of quality are important and complex issues facing the State.

The State of Wyoming is considered to be a water producing state to the Colorado River Basin, the Snake River Basin, and the Missouri River Basin. Approximately 15.5 million acre feet of water is produced in Wyoming annually, with approximately 12 million acre feet obligated for downstream use through compacts and treaties. Wyoming has embarked on a large-scale water development program with the intended purpose of capturing for its use as much of the excess water produced as possible. The problems associated with the capture, diversion, dispersal, and re-use of these water resources are encompassing. In addition, being better able to forecast quantity and quality of water availability to downstream users is extremely important.

To address the problems and generate needed information associated with water conservation, development, and re-use, a truly interdisciplinary effort, well-managed and coordinated, is essential. The Wyoming Water Research Center is organized in such a manner and can call upon the diverse set of disciplinary expertise necessary to address key issues for the state and the region.

PROGRAM GOALS AND PRIORITIES

In an attempt to address those problems most critical to the State, the Wyoming Water Research Center (WWRC), in consultation with its Research Review and Priorities Advisory Committee, established the following three major areas of water research: 1) evaluation of historical and current water use practices; 2) demand analysis and water resources planning and 3) development of water resources. These three major areas include water quality and quantity, as well as the economic and social aspects of water research. We believe this emphasis provides a very logical, step-wise approach to addressing water research needs in the State of Wyoming. Certainly, projects dealing with the economic, technical and legal aspects of historical and current water use practices are necessary for the proper analysis of need for additional water resources development and the appropriate development of water resources can best be determined with information resulting from efforts under items 1 and 2 above. This framework should allow for a meaningful priority structure that can lead to information development germaine to the needs of the State and the western United States.

In keeping with the Center's attempt to implement priority research, we have indicated how our projects relate to the various subjects falling under our three major priorities. Figure 1 is a schematic of how our federal projects meet some of our state priorities.

Figure 2 illustrates the categories of research under which specific projects fall for the federal program. These categories are based on the five-year plan and priorities set under the OWP program and are reflective of our continuous priority listing.

FIGURE 1
STATE OF WYOMING RESEARCH PRIORITIES AND PROJECTS
FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER
Fiscal Year 1984

RESEARCH PROJECTS FY84	STATE OF WYOMING RESEARCH PRIORITIES												
	Stream Structure & Management	Water Quality	Watershed Development & Management	Agricultural Uses	Information Coordination & Transfer	Underground Water Resources	Hydroelectric & Geothermal Potential	Water Quantity	Waterways Construction & Development	Economic Analysis	Trans-basin Diversion	Water Law in Wyoming	Multiple Uses
Project No. 02 - Organic Contaminant Transport in Groundwater		X				X							
Project No. 03 - Trout Density in Forested Mountain Streams	X		X										
Project No. 04 - Secondary Costs & Benefits--Water Development Projects										X			
Project No. 05 - LANDSAT Imagery to Measure Snowcover & Estimate Runoff			X					X					
Project No. 06 - Furrow Irrigation Through Controlled Soil Compaction				X									

FIGURE 2
FEDERAL RESEARCH PRIORITIES AND PROJECTS
FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER
Fiscal Year 1984

RESEARCH PROJECTS FY84	FEDERAL RESEARCH PRIORITIES								
	Hydrologic Processes					Legal, Institutional & Economic Consideration in Water Management & Development			
	Montane Zones	Stream Systems	Groundwater/ Groundwater Recharge	Agriculture/ Conservation	Water Quality	Trans-basin Diversions Legal, Institutional and Economic Concerns	Financial Alternatives for Water Development Efficiency/Equity Consideration	Conservation/ High Energy Cost Adjustments in Agriculture	Water Planning Models
Project No. 02 - Organic Contaminant Transport in Groundwater			X		X				
Project No. 03 - Trout Density in Forested Mountain Streams	X	X							
Project No. 04 - Secondary Costs & Benefits--Water Development Projects							X		
Project No. 05 - LANDSAT Imagery to Measure Snowcover & Estimate Runoff	X	X							
Project No. 06 - Furrow Irrigation Through Controlled Soil Compaction				X					

RESEARCH PROJECT SYNOPSES

SYNOPSIS

PROJECT NUMBER: 02

Start: 10/1/83
End: 9/30/85

TITLE: Organic Contaminant Transport in Groundwater, Surface Water and Surface Water Sediment: A Case Study of a Wood-Treating Plant.

PRINCIPAL INVESTIGATORS: Harold Bergman and Michael Crossey, Department of Zoology and Physiology, University of Wyoming, Laramie.

COWRR: 5B

CONGRESSIONAL DISTRICT: First

DESCRIPTORS: groundwater, surface-groundwater relations, contamination, organic compound, water pollution sources, water transport, creosote, sediment, mini-piezometers, soil columns

PROBLEM AND RESEARCH OBJECTIVES

Organic contaminants in groundwater and surface waters are more often than not complex mixtures. Transport and fate models based on single compound parameters do not adequately predict how these complex mixtures will move through the environment.

The research objectives of this study were: (1) to monitor the Laramie River adjacent to a wood-treating facility using mini-piezometers and seepage meters in order to define the off-site migration of creosote wastes which underlie approximately 80 acres of this site. In addition, sediments taken downstream from the site were analyzed using high performance liquid chromatography (HPLC) and gas chromatography/mass spectroscopy (GC/MS) in order to define the extent of the downstream contamination.

Laboratory studies were also initiated using soil columns to investigate the effect of oil/water ratios on the migration patterns of organic compounds through the columns.

METHODOLOGY

Field monitoring was performed using teflon mini-piezometers driven approximately three to four feet below the bed surface of the Laramie River. In this manner groundwater leaving the site and entering the Laramie River could be sampled before it became diluted by the water flowing in the channel. Seepage meters were also used to monitor the waters entering the river channel from the site. Sediment samples collected downstream of the site were extracted and analyzed using HPLC and GC/MS in order to qualitatively and quantitatively measure the extent of the contamination downstream of the site. In laboratory experiments glass columns (15 cm ID x 60 cm) packed with 2 mm glass beads were used to investigate the effects of creosote/water mixtures on the migration rate of a single organic compound (naphthlene).

PRINCIPAL FINDINGS AND SIGNIFICANCE

Field studies have shown that in 1983 oily seeps were entering the river and severe contamination by oil globules was occurring downstream of the wood-treating facility. Subsequent monitoring with mini-piezometers indicated the presence of several seeps. In 1984 and through the summer of 1985 no free oil was detected in the river, however we did detect a large oil body three to four feet below the surface of the bed sediments in the Laramie River adjacent to the site. The presence of this oily deposit has caused the operators to move the river channel as a first step in the remedial action plan to halt further contamination of the Laramie River. Sediment sampling has shown that site related contaminants can be detected as far downstream as

three miles and that for sites sampled in 1983 and 1985 the contamination has declined significantly over the past two years. These quantitative data corroborate qualitative visual inspection of the river over the last two years.

Soil column experiments have shown that organic contaminants as emulsions move faster through the packed columns than did a dissolved single compound (naphthlene). Therefore, concentrations of creosote in water which are high enough to form multi-phase or emulsive type oil/water mixtures may exhibit rapid migration through the subsurface.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

Water Quality Concerns: Organic Pollutants. American Fisheries Society, 115th Annual Meeting. Sun Valley, Idaho, September 8-12, 1985.

Transport of Creosote Wastes in an Alluvial Aquifer-Riverine System. M.J. Crossey, J.A. Cherry and H.L. Bergman. Society of Environmental Toxicology and Chemistry, 6th Annual Meeting. St. Louis, MO, November 10-13, 1985.

M.S. THESES: none

PH.D. DISSERTATION

This project forms part of the research for Michael J. Crossey's Ph.D. Expected completion date of August 1986.

SYNOPSIS

PROJECT NUMBER: 03

Start: 10/1/83
End: 9/30/85

TITLE: Validation of a Simple Model for Predicting Trout Density in Forested Mountain Streams

PRINCIPAL INVESTIGATORS: Wayne Hubert and Thomas Wesche, Wyoming Cooperative Fishery and Wildlife Research Unit, University of Wyoming and Wyoming Water Research Center, University of Wyoming, Laramie, respectively.

COWRR: 6G

CONGRESSIONAL DISTRICT: First

DESCRIPTORS: aquatic habitat, trout, stream fisheries, mathematical models, prediction

PROBLEM AND RESEARCH OBJECTIVES

A rapid measure of trout stream quality is needed by land managers, planners, and biologists responsible for managing forests in mountain areas. The goal of this project was to build and validate a simple, multiple-regression model to predict trout abundance in forested mountain streams from easily measured instream habitat and geomorphological variables. Specific objectives were (1) to describe the physical components of habitat and trout abundance in stream reaches in forested mountain areas of Wyoming, and (2) to statistically determine the correlation between trout standing stock measured in the stream reaches and values predicted by the model.

METHODOLOGY

Second to fourth order stream reaches in forested mountain areas at elevations exceeding 2,200 m (7,200 ft) were selected from watersheds in Wyoming. Reaches were selected for variation in habitat features.

Within each stream reach trout standing stock was estimated by standard depletion techniques using electrofishing gear. Seventeen instream habitat variables, as well as 12 geomorphological variables, were also measured. Multiple-regression models were developed using data from previous years and the data obtained during this study. The models were tested using data from this study.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The best model accounted for 51 percent of the variation in trout abundance (sample size = 65) using four variables, three geomorphological variables measured from topographic maps and one instream habitat variable measured at the stream reach. A model with three independent instream habitat variables accounted for 31 percent of the variation, while a model with three geomorphological variables accounted for 36 percent. Correlations between predicted and actual trout abundance for 11 test reaches were 0.80 for the best model, 0.32 for the instream habitat model, and 0.75 for the geomorphological model. Rapid data collection and a mechanism for quick, reliable preliminary decision making should make these models attractive to managers.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

Lanka, R., W. Hubert and T. Wesche. 1984. Evaluating visual stream habitat assessment techniques to model trout biomass. Proc. Colo.-Wyo. Chap. Amer. Fish. Soc. 19:21-26. Paper presented at annual meeting, March 1984, Ft. Collins, CO.

Lanka, R., W. Hubert and T. Wesche. In press. Influence of geomorphology on trout abundance. Proc. Colo.-Wyo. Chap. Amer. Fish. Soc. 20. Paper presented at annual meeting, March 1985, Laramie, WY.

Lanka, R., W. Hubert and T. Wesche. In press. Rapid prediction of trout stream quality. In Issues and Technology in the Management of Impacted Western Wildlife, Thorne Ecological Institute, Boulder, CO. Paper presented at symposium, February 1985, Glenwood Springs, CO.

M.S. THESIS

Lanka, R.P. 1985. Modeling trout standing stock in small Wyoming streams based upon easily measured habitat and geomorphological characteristics. M.S. Thesis. University of Wyoming, Laramie.

Ph.D. DISSERTATIONS: none

SYNOPSIS

PROJECT NUMBER: 04 Start: 10/1/83
End: 9/30/85

TITLE: Improving the Estimation of Secondary Costs and Benefits Associated with Wyoming Water Development Projects

PRINCIPAL INVESTIGATORS: Edward Bradley, James Jacobs, University of Wyoming and F. Larry Leistritz, North Dakota State University

COWRR: 6B CONGRESSIONAL DISTRICT: First

DESCRIPTORS: water resources development, economic aspects, benefit-cost analysis, impact assessment, secondary benefits, project evaluation, fiscal impacts

PROBLEM AND RESEARCH OBJECTIVES

Although demand for water has continued to grow in recent years, federal appropriations for water development projects has dwindled. Several western states, especially Wyoming, have decided to expand their own programs to compensate for reductions in federal water development activity.

The shift in water development responsibilities to states has many implications for the planning and selection of water projects. First, benefit-cost analysis from a state's perspective cannot be used to evaluate the total (i.e., primary and secondary) effects of a project as easily as it can from the federal perspective. From the federal perspective secondary benefits and costs cancel each other; but from the state perspective secondary benefits may be significantly less than or greater than secondary costs. Second, a state could choose to use water development as a means not only to stimulate state economic growth, but also to redistribute income and economic growth to economically

depressed groups and areas. If this is the case, state officials will want to know how the benefits and costs of any prospective project will be distributed. Given the increase in responsibilities for water development, states need to institute their own policies and procedures for water resource development, ones consistent with their own goals and oriented from their own accounting stances.

The overall objective of this study is to demonstrate that impact assessment techniques can be used to identify and quantify the expected secondary effects and distributional effects of state water development projects. Embodied in this overall objective are the following specific objectives:

1. To identify and quantify the expected secondary and distributional effects of developing the proposed Westside irrigation project.

2. To identify and quantify these expected effects for the proposed Middle Fork project.

3. To discuss how inclusion of the expected secondary effects and expected distributional effects contributes to the economic analyses of both these Wyoming projects.

METHODOLOGY

Two scenarios for developing the Westside irrigation project and two scenarios for developing the Middle Fork project were first specified and then assessed in terms of the magnitude and distribution of the economic, demographic and public sector impacts. Construction of large-size water projects may provide substantial benefits to local communities by being a stimulus for growth in local economies and local tax

bases. The direct effects of a project on local business activity, employment and income induce substantial secondary effects. Secondary effects arise from the multiplier process, whereby an initial economic stimulus to a local economy leads to increased sales by local firms which in turn purchases additional inputs from other local firms and households. Estimating the magnitude of secondary economic activity (i.e., induced employment, business volume and income) resulting from a water project is central to the evaluation of the total change in area employment, business volume and income resulting from a project. Secondary employment estimates are important for making realistic projections of population growth and public service needs associated with water development. Estimates of secondary business activity and income enable analysts to forecast changes in local and state revenues.

Most socioeconomic impact assessments are done with site specific computerized models that embody interrelated input-output, demographic, residential allocation and public sector fiscal impact sub-components. Fortunately, there is an existing computerized impact assessment model for use in six multiple-county regions in Wyoming. This model can project business activity and personal income at the regional level and estimate employment, population, and public sector costs and revenues at the state, county and community levels.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The analysis of the Westside irrigation project involved two project scenarios. The first scenario was for a project which would irrigate 9,026 acres, cost $10,444,000 to construct and generate

3,766,000 in agricultural revenue. The second scenario was for a larger project which would irrigate 20,718 acres, cost $15,878,000 to construct and generate $8,619,000 in agricultural revenue. Both projects would produce net public sector surpluses at the local level, but deficits for the state overall.

The analysis of the Middle Fork project involved two scenarios also. The first involved construction of a reservoir to yield 25,000 acre feet of water annually. This project would cost $10,958,000 to construct and supply supplemental irrigation to 4,600 acres of presently irrigated land and for irrigation of 900 acres of new land. The second scenario was the same as the first except that a 375 million standard cubic feet per day (MMSCFD) coal gasification plant which uses 12,500 acre feet of water was added. The total costs of the first scenario far exceeded its total benefits, but the second scenario would generate significant net benefits for both the private and public sectors in Wyoming.

Irrigation, due to the tax structure of Wyoming, does not have the potential to generate public sector surpluses, but projects which would supply water for energy development certainly do.

The impact assessment model used in this study readily provided information on the expected effects of proposed water projects.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS: none

M.S. THESES: none

PH.D. DISSERTATIONS: none

SYNOPSIS

PROJECT NUMBER: 05

START: 10/1/83
END: 9/30/85

TITLE: Prediction of Annual Runoff Pattern Using LANDSAT Imagery to Measure Snowcover and Estimate Runoff

PRINCIPAL INVESTIGATOR: Ronald Marrs, Department of Geology and Geophysics, University of Wyoming, Laramie

COWRR: 2A

CONGRESSIONAL DISTRICT: First

DESCRIPTORS: rainfall-runoff relationships, LANDSAT imagery, snowcover, snow surveys, water management, hydrologic models, streamflow forecasting, snowpack, prediction

PROBLEM AND RESEARCH OBJECTIVES

Snowpack has been traditionally monitored by selected, on-site recording stations and periodic sampling for water content. These measurements can be used to forecast runoff if variables such as rate and timing of spring warm-up and uptake of moisture by soils and vegetation can be taken into account. Such techniques have been proven effective, but are subject to limitations with regard to accuracy and practicality. LANDSAT data can be used to effectively augment these measurements and improve water forecasts.

The goal of this research was to develop a practical technique for using LANDSAT imagery to measure snowpack and estimate expected runoff throughout Wyoming.

METHODOLOGY

The method used was to correlate measured runoff for past years with estimates of snowpack derived from interpretations of satellite

imagery for these same years. Correlations between snowpack and runoff for each drainage area provide a basis for estimating expected runoff from current snowpack measurements derived from the latest satellite data. The historical relationships between snowcover and runoff also allow estimates of the timing of peak runoff and waning runoff using the satellite data as a means of estimating current size and condition of runoff. The LANDSAT images also provide an archival record of snowcover as it accumulates and melts each year. This record allows for retrospective modification of predictor relationships and re-assessment of unusual or transient phenomena that might affect the runoff pattern.

Estimation of the area of snowcover is made from a sequence of LANDSAT images selected from coverage obtained during several snowmelt seasons. Snowcover measurements are obtained by electronic planimeter using a video-analogue image analyzer. The snowcover measurements are plotted against measured streamflow summed over the melt season. As cumulative runoff increases, snowcover decreases each year. The empirical relationship derived from the correlation of these data is evaluated and compared to similar curves for other snowmelt seasons to derive a composite relationship that represents the "typical" pattern of snowmelt versus runoff for each watershed. This typical curve can then be used to forecast volume and timing of runoff during the spring snowmelt using the current LANDSAT imagery to assess the condition of the snowpack in a given watershed. As each successive image is returned from the satellite, the forecast can be modified to accommodate any unexpected changes in the snowmelt pattern.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Composite curves were compiled for each Wyoming watershed where adequate data were available for several seasons. Both the annual and composite curves are useful for predicting the expected runoff from the most recent satellite images. Dates for beginning, peak, and end of spring snowmelt can be predicted.

The groundwork is now sufficiently complete and the accumulated database is minimally adequate for operational application of this technique to water management in Wyoming. The techniques appear to be both effective and practical. Current and proposed tests will establish timeliness and reliability with which these new techniques can provide runoff estimates from satellite data.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

Marrs, R.W. 1985. Snowpack estimates from satellite imagery and relationships to spring melt patterns. Wyoming Water '85, Symposium on Water Resource Problems and Research in Wyoming, University of Wyoming, Laramie, May 2-3, 1985.

Marrs, R.W. 1985. LANDSAT: A tool for monitoring snowmelt and predicting runoff patterns for mountain watersheds. 10th Annual William T. Pecora Remote Sensing Symposium, Ft. Collins, CO, August 20-22, 1985.

M.S. THESES: none

PH.D. DISSERTATIONS: none

SYNOPSIS

PROJECT NUMBER: 06

START: 10/1/83
END: 9/30/85

TITLE: Improved Furrow Irrigation Efficiency Through Controlled Soil Compaction

PRINCIPAL INVESTIGATORS: James L. Smith and John Borrelli, University of Wyoming, Laramie

COWRR: 3F

CONGRESSIONAL DISTRICT: First

DESCRIPTORS: irrigation engineering, irrigation efficiency, soil compaction, furrow irrigation, furrow shape, erosion, sediment transport, infiltration

PROBLEM AND RESEARCH OBJECTIVES

A significant portion of the surface irrigated cropland in the western United States is located in alluvial valleys. Soils in these valleys are typically sandy, and have very high water infiltration rates. The problem of high infiltration rates is particularly severe when minimum tillage practices are used in these soils.

Furrows are normally formed using a furrow opener. This device forms a V-shaped furrow and leaves the surface relatively loose and rough. These factors contribute to high infiltration and to erosion and transport of sediments both within the field and with tail water.

A compaction roller will firm and smooth the furrow wall and bottom. Compaction reduces the infiltration rate, and water advances more rapidly across the field because of the smooth furrow surface. Water intake, thus, is more nearly uniform along the entire length of the furrow. Less total water is required and water is applied more uniformly, and essential plant nutrients are retained in the soil.

Three basic shapes can be used for the furrow cross section: triangular, trapezoidal and parabolic. The triangular shape is the easiest to manufacture, and is typical of the shape made by most furrow openers. Parabolic has the advantage of being the most stable and should have different advance and infiltration characteristics due to the different wetted perimeter and hydraulic radius. The trapezoidal is basically a compromise between the triangular and parabolic, and thus, was not considered for this research.

The current research was conducted during the 1985 growing season at the University of Wyoming, Powell Research and Extension Center. At Powell, the experiments were conducted on conventionally tilled dry beans with a furrow length of 320 m. Water was delivered using 50.8 mm siphon tubes. The soil at Powell was classified as a clay loam, but its irrigation characteristics resembled those of a coarse sand. The soil formed very coarse granular aggregates and thus, had high water intake rate and required an initial flow rate in excess of 90 l/min to move water down the furrow at a reasonable rate. The maximum flow rate for non-erosive flow should have been less than 76 l/min.

Research objectives were:

1. To evaluate the hydraulic, infiltration and erosion stability of compacted triangular and parabolic furrows.

2. To develop a method for predicting the required furrow compaction effort to achieve desired hydraulic and infiltration characteristics.

METHODOLOGY

The furrow compaction machine was fabricated to mount on the three-point hitch of an agricultural tractor. It consisted of five compaction units: two 110 degree V wheel packers, two parabolic packers, and one conventional furrow opener. Track eliminators were located behind the tractor wheels. The compaction effort was varied by placing weights on the packer wheels.

Infiltration was measured using blocked furrows 1 m in length. Geometric differences between triangular and parabolic furrows were accounted for by adjusting the depth of water in the infiltrometer.

The field was laid out randomly with compaction level as the variable. During the initial layout, the field was surveyed to determine slope, and four irrigation advance stations were established at 80 m intervals. After forming and compacting the furrows, soil penetration resistances were measured. Penetration resistance was compared with similar values obtained in laboratory compacted soils to determine compaction energy levels.

Furrow water flows were maintained constant by a constant head tank formed in the head ditch. Actual flows were determined by calibrating siphon tubes. Advance and recession times were recorded at the advance stations.

Flumes were set just beyond the final advance stations for collecting sediment samples. Sediment samples were filtered and oven dried. Observations of the flumes indicated that alternative methods would be required to determine furrow flows.

PRINCIPAL FINDINGS AND SIGNIFICANCE

1. Deep compaction by the tractor tire was beneficial in reducing infiltration.

2. Furrow shape is an important consideration for improved furrow irrigation. However, when comparing different furrow shapes, it is necessary to consider the geometry of the furrow and the effect of furrow geometry on infiltration, furrow advance, and depth of water in the furrow as a function of time. Traditional methods of analyzing furrow irrigation are unsatisfactory for comparing furrow shape.

3. A model of furrow flow is being developed which will permit comparative evaluation of the triangular and parabolic furrows considered in this research. It will also provide the necessary flow data required to evaluate sediment transport from the furrows.

4. Using a plate compaction test, field furrow soil penetration resistance and the results of furrow hydraulic and infiltration tests, a procedure can be developed to predict the level of compaction required to produce desired furrow irrigation results.

PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

Three papers will be offered for the 1986 Annual Meeting of the American Society of Agricultural Engineers. These will include a paper on the hydraulic characteristics of the parabolic and triangular furrows, a paper on the sediment transport from the furrows and a paper on the compaction energy required to form furrows.

M.S. THESES

Larsen, John F. 1985. Design and Evaluation of an Irrigation Furrow Packing System. Expected completion date, December 1985.

Hinton, Larry D. 1986. Compaction of Triangular and Parabolic Irrigation Furrows. Expected completion date, December 1985.

PH.D. DISSERTATIONS: none

INFORMATION TRANSFER ACTIVITIES

DISSEMINATION OF RESEARCH RESULTS

Wyoming Water '85:

A Symposium on Water Resource Problems and Research in Wyoming. May 2-3, 1985, sponsored by the Wyoming Water Research Center at the University of Wyoming. 118 attendees. Proceedings in press.

Topics included: Water Issues and Problems--the Industrial, Municipal, Agricultural and Environmental Viewpoints; Water Economics; Water Management; Water Law; Water Development; Water Quality; Ground Water; and the Federal Role in Federal-State Relationships in Water Development Projects. Three of the presentations were the results of research funded by the U.S. Geological Survey 1984 federal program and two from state-funded projects through the Wyoming Water Research Center.

Speakers were selected from: Wyoming Mining Association, Cheyenne Board of Public Utilities, Wyoming Farm Bureau Federation, Wyoming Game and Fish, U.S. Department of Agriculture, Consulting Chemical Engineer, Casper Parks and Recreation Department, Colorado State University, Wyoming State Attorney General's Office, private law firm, Wyoming State Engineer, Powder River Basin Resource Council, Wyoming Oil and Gas Commission, Casper-Alcova Irrigation District, U.S. Forest Service, U.S. Geological Survey, former Wyoming congressman, and representatives from U.W. Departments of Geology, Range Management, Agricultural Economics, Agricultural Engineering, Mathematics, Plant Science.

Wyoming Water Bibliography

The Wyoming Water Bibliography, a service project requested by the State, is one of the most comprehensive, multidisciplinary, computer-based bibliographic storage and retrieval systems regarding Wyoming's water resources. Currently operational, the WWB contains approximately 12,500 citations which can be searched, free of charge, on a request basis. The User's Manual for the system is available and has been mailed to over 1,000 people in the State involved with water issues, including legislators, agency personnel, representatives of county and municipal governments, libraries, special interest groups and interested members of the private sector. Seminars have been given at all of the regional community colleges.

Water Resources Data System

The Water Resources Data System (WRDS) has provided water related data to Wyoming researchers for over a decade. The system, through the years, has developed into the most comprehensive single source of surface and ground water quantity and quality, snow quantity and climatological data available for Wyoming. The broad applicability of the system is attested to by the variety of its users. The system has provided information to many state, federal, county and municipal agencies and private firms.

The Wyoming Water Research Center uses several networks to inform the public and private sector of research activities in the State. UW faculty, working through the Wyoming Water Research Center, have reported their research results in professional journals and at

conferences. Research results are also disseminated through technology transfer efforts by organized workshops, seminars, etc.

Specific documents are circulated among users in the State. These are:

1. Information brochure: An information brochure on the Wyoming Water Research Center was designed to inform the public, state, and federal agencies, faculty and students of the mission, organizational structure, and programs of the WWRC. To date, the brochure has been distributed to universities, industry, state and federal agencies, industrial organizations, and many other private and public entities.

2. "WWRC News": In "Wyoming Water Flow Newsletter", published monthly by the Wyoming Water Development Association. Subscriptions total approximately 700.

3. WWRC Progress Reports. Distributed annually to advisory committees and to Wyoming State Legislature.

4. Water Center Series Publications List.

5. Directory of Water Resources Expertise, Wyoming Water Research Center and University of Wyoming, Issue No. 1, September 1985.

6. Capsule reports on each project funded with monies available through the Center are in progress.

In addition to the above activities, the following meetings were attended and presentations made by the Water Center director, associate director and/or staff as listed below. This past year has been extremely busy with these activities and oriented toward transferring

information to potential users as well as making individuals and organizations aware of the WWRC and it's activities and products.

- American Fisheries Society National Meeting, September, 1985, Sun Valley, Idaho.
- Missouri River Basin Directors Meeting, September 18-19, 1985, Denver, Colorado.
- Mitigation of Acidification Effects Symposium, Muskoka Conference '85, September 19, 1985, Muskoka, Toronto, Ontario Canada.
- Non-Profit Resource Use Organizations Roundtable, planning for "Wyoming Futures Project", September 15-17, 1985, Ucross, Wyoming.
- Cooperative Research on Acid Deposition in the West Planning Meeting, August 23, 1985, Idaho Falls, Idaho.
- ASCE Hydraulic Division Specialty Conference, August 12-17, 1985, Orlando, Florida.
- Third International Symposium on Regulated Streams, August 4-8, 1985, Alberta, Canada.
- Citizens Acid Rain Coordination Committee, appointed by Governor, July 22, Cheyenne and September 11, 1985, Laramie, Wyoming.
- Western Acid Deposition Task Force Meeting, July 10-12, 1985, Colorado Springs, Colorado.
- Governor's 1985 Resource Tour, Teton and Lincoln Counties, June 19-21, 1985, Wyoming.
- University of Wyoming Forest Service Coordination Commission, June 7, 1985, Laramie, Wyoming.
- Wyoming Affairs Meeting, June 3, 1985, Cheyenne, Wyoming.
- Nonpoint Source Pollution Conference, May 19-22, 1985, Kansas City, Kansas.
- NATO Advanced Study Institute on Engineering Reliability and Risk in Water Resources, May 19-June 2, 1985, Tucson, Arizona.
- Wyoming Water '85, A Symposium on Water Resource Problems and Research in Wyoming, University of Wyoming, May 2-3, 1985, Laramie.

- Western Atmospheric Deposition Task Force Meeting, April 4, 1985, Denver, Colorado.

- Riparian Ecosystems Management Conference, April, 1985.

- Buffalo Bill Dam Modification Agreement Signing Ceremonies, March 29, 1985, Cody, Wyoming.

- Lake Acidification and Fisheries Workshop, Western Aquatics, Inc. and University of Wyoming, March 25-27, 1985, Laramie.

- American Fisheries Society Colorado-Wyoming Chapter Meeting 1985, March 13-14, 1985, Laramie, Wyoming.

- Second Hydrology Symposium on Surface Coal Mining in the Northern Great Plains, Gillette Area Groundwater Monitoring Organization and Wyoming Water Research Center, University of Wyoming, February 26-28, 1985, Laramie.

- National Conference on Water Resources Research, Universities Council on Water Resources, February 4-6, 1985, Chevy Chase, Maryland.

- 11th Annual Water Management Seminar, Eastern Wyoming College, January 15, 1985, Torrington, Wyoming.

- 15th Annual Water Management Seminar, Northwest Community College, January 7-8, 1985, Powell, Wyoming.

- Wyoming Water Law Short Course for Wyoming Legislators, January 4, 1985, Cheyenne, Wyoming.

- Wyoming Water Development Board Meeting, January 3, 1985, Cheyenne, Wyoming.

- National Association of Water Institute Directors Annual Meeting, November 8-9, 1984, Arlington, Virginia.

- Wyoming Association of Conservation Districts Annual Meeting, State Conservation Commission, November 1-3, 1984, Riverton, Wyoming.

- Wyoming Water Development Association Water Conference and Annual Meeting, November 1-2, 1984, Douglas, Wyoming.

- Environmental Toxicology and Chemical Analysis Symposium for the Centennial Meeting of the Association of Official Analytical Chemists, October 31-November 2, 1984, Washington, D.C.

COOPERATIVE ARRANGEMENTS

As specified in its charter, the Wyoming Water Research Center has been responsible for 1) Service, 2) Extension, 3) Research and 4) Instruction. The Director, in keeping with the Center's charter, and in cooperation with the State of Wyoming, has spent the majority of his time in organizing the following services.

1. Service:

Service to State Agencies

- Continual liaison with state agency officials. Table 1 lists cooperating state agencies and Table 2 lists specific projects performed in response to state requests.
- Basic technology transfer to state agencies and Wyoming water users and managers.
- Serve as advisor to Wyoming Water Development Commission.
- Continued attempts to integrate state and federal research programs.
- Attend Governor's Water Forum.
- Attend meetings regarding specific research projects.

University Service

- Serve on University committees.
- Continued effort to apprise faculty members of research needs and opportunities in water-related research.
- Work with academic standards committee on Water Resources curriculum.
- Serve on appropriate graduate student committees.
- Serve on appropriate national and international technical review panels.

TABLE 1

COOPERATING WYOMING STATE AGENCIES

Attorney General's Office

Conservation Commission

Economic Development & Stabilization Board

Department of Agriculture

Department of Environmental Quality
Air, Land and Water Quality Divisions

Disaster and Civil Defense

Game & Fish Department

Governor's Office

Highway Department

Industrial Siting Administration

Legislative Services Office

Oil and Gas Conservation Commission

Recreation Commission

State Engineer's Office

State Planning & Coordination

Travel Commission

U.S. Geological Survey District Office

Water Development Commission

Wyoming Geological Survey

TABLE 2

Service-to-State
FY1984

- Wyoming Integrated River System Operation Study (WIRSOS) - a Comprehensive, Hydrologic and Streamflow Basin Model--Evaluation of the Model and Use for Basins Throughout Wyoming (Attorney General's Office, Wyoming Water Development Commission and State Engineer's Office). Continued financial support.

- Collection of field data involving evapotranspiration and associated climatic measurement--Upper Green River (Wyoming Water Development Commission and UW Agricultural Engineering). Continued financial support.

- North Platte Model - Update to evaluate new development (Wyoming Water Development Commission and State Engineer's Office). Continued financial support.

- Response to request for information on Soil Conservation Service Snow Survey and Water Supply Forecast Reporting System (Governor's Office).

- Completion of Wyoming Geographic Information Survey (Governor's Office).

- Acidic Deposition Coordinating Committee. Appointed by the Governor, the Director serves on committee to provide focus and direction for the State's efforts in research, monitoring, evaluating and developing policy as appropriate on acidic deposition in Wyoming (Governor's Office).

- Conveyance Loss Study, Water Division No. 2, along Piney and Clear Creeks near Buffalo, Wyoming (State Engineer's Office).

- Reconnaissance Survey: Trace Metals Concentrations in Wind River Glaciers (Western Wyoming College, Rock Springs).

- Production of Input-Output Model, county-by-county water use in Wyoming (Economic Development and Stabilization Board, Wyoming Water Development Commission and Recreation Commission).

Other

- Continued effort to be cognizant of regional and national water issues and research opportunities.
- Participation in state water resource management symposium.
- Transfer of research results to appropriate users.
- Director serves as member of the National Coal Council.

2. Extension

One of the four major missions of the WWRC involves extension activities. The WWRC believes in a strong water resources extension effort and the Director is currently recruiting appropriate expertise to expand this activity using state funding. It is our intention that both state and federal research results be packaged and presented in a useful and cogent manner to maximize the utilization of research effort and results.

3. Research

- Federal Program FY84

Research accomplishments of the FY84 Federal Water Research Program were reviewed by the Director. The Wyoming Water Research Center funded a project to update the perceived water research needs from the public, private, and governmental sectors in the State of Wyoming. The results of this study are now available and will be used to help establish regional priorities for the Water Resources Institute Program.

- Federal Program FY85

The Director prepared the Federal Water Research Program FY85 Request for Proposals which was distributed among interested faculty on

campus. Twelve proposals were received and reviewed by state agencies, representatives of the private industry, and regional Water Institute/ Centers. Three were funded under the program.

4. Instruction

The Wyoming Water Research Center is cooperating with academic departments throughout the campus to provide master of science degree programs which contain high quality multidisciplinary training in water resources. The master of science degrees offered through these affiliations are awarded as specialty options within the existing master of science programs currently housed within the sponsoring departments. The water resources emphasis will be acknowledged on the graduate transcript and thereby certify to potential employers that the candidate has completed an attractive in-depth multidisciplinary course program in the broad area of water resources.

ADVISORY STRUCTURE

The organizational structure and operational procedures of WWRC for a high degree of accountability and relevance to state and regional water research seems to be working well. In 1982, the WWRC was restructured to include a Research Review and Priorities Committee (RRPC) appointed by the Governor of the State of Wyoming and the President of the University. The membership was designed to reflect the interests and inputs of the Executive Office, the legislative branch of government, the academic community and the University administration (Table 3). The Committee meets at least three times annually to discuss

TABLE 3

WYOMING WATER RESEARCH CENTER

Research Review and Priorities Committee

Chairman:

Dick Hartman
State Planning Coordinator
Herschler Building
Cheyenne, Wyoming 82002
(307) 777-7574

Executive Secretary:

Robert W. Brocksen, Director
Wyoming Water Research Center
Room 151, VA Building
University of Wyoming
(307) 766-2143

U.W. Appointees:

Donald L. Veal, President
Office of the President
Old Main, Room 206
766-4121

Robert A. Jenkins
Vice President for Research
Old Main, Room 408
766-5353

Dennis H. Knight
Department of Botany
Aven Nelson, Room 135
766-3291

Quentin Skinner
Range Management
Agriculture Bldg., Room 2028
766-4139

(All University of Wyoming, Laramie, Wyoming 82071)

Executive Appointees:

Governor Ed Herschler
State Capitol Building
Cheyenne, Wyoming 82002
777-7434

Willard Rhoads
Water Development Commission
P.O. Box 637
Cody, Wyoming 82414
587-3787

Paul Schwieger
DEPAD
Division of Water Development
Herschler Building
Cheyenne, Wyoming 82002
777-7284

Warren White (alternate)
Governor's Office
State Capitol Building
Cheyenne, Wyoming 82002

Legislative Appointees:

George R. Salisbury, Jr.
Representative, Carbon County
Savory, Wyoming 82331
383-2430

Donald R. Cundall
Senator, Goshen-Platte County
Wendover Route
Guernsey, Wyoming 82214
322-3311

Water Center activities, research needs as they may have been perceived to change, and to approve projects presented.

Prior to presentation of projects to the Advisory Committee, a review process that includes relevant state agencies in addition to scientific peer review has been completed. This process has insured good science directed toward issues meaningful to water research needs in the state and the region.

A Citizens Water Issues Advisory Council (CWIAC) was formed in January 1984 and consists of members selected by the Governor and the University of Wyoming President (Table 4). The Council was formulated to represent a) agriculture, b) recreation, c) municipalities, d) National Forest Service, Bureau of Land Management, Bureau of Reclamation, National Fish and Wildlife Service, e) consulting engineers, f) State Legislature, g) industry, h) environmental interests, i) private citizens, j) legal profession, k) political action groups (e.g., League of Women Voters), l) Wyoming Higher Education System, and m) state agencies. The Council is charged with collecting input from constituencies, water experts within and outside the State, and other available sources, identifying water concerns and transmitting those concerns to the Research Review and Priorities Committee. A joint meeting of both the RRPC and CWIAC was held in September 1984.

TABLE 4

WYOMING WATER RESEARCH CENTER

Research Review & Priorities Committee

CITIZENS WATER ADVISORY COUNCIL

Myron Goodson, Chairman
Citizens Water Advisory Council
Box 429
Sundance, WY 82729
(307) 283-2407

Walter Yose, Jr.
P.O. Box 94
LaBarge, WY 82123
(307) 386-2322

Beryl Churchill
848 Road 10-A, Route 3
Powell, WY 82435
(307) 754-4865

Philip Hocker
P.O. Box 458
Wilson, Wyoming 83014
733-6116 or 733-6345

John Morris
10401 Experimental Farm Road
Cheyenne, WY 82009
(307) 634-7561

Jim Rumery
North Portal Road
Riverton, WY 82501
(307) 856-7477

Russell Michael
Route #2
Torrington, WY 82240
(307) 788-1711

TRAINING ACCOMPLISHMENTS

Shown by fields of study and training levels indicated, the numbers of individuals participating in projects financed in part through the Fiscal Year 1984 Program.

Training Category	Training Level				
		Graduate			
	Under-Graduate	Master's Degree	Ph.D. Degree	Post-Ph.D.	Total
Engineering					
Agricultural		2			
Civil					
Environmental					
Biology					
Ecology			1		
Fisheries, Wildlife and Forestry		1			
Agronomy					
Chemistry					
Hydrology					
Resources Planning					
Law					
Economics					
Geography					
Other - specify					
TOTAL		3	1		