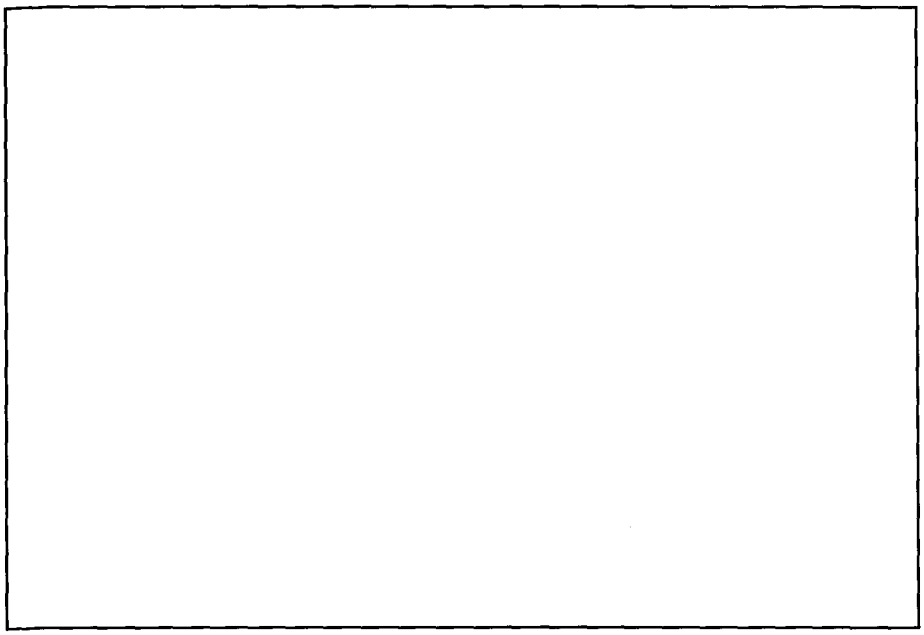
Colorado State University

WATER RESEARCH IN THE ROCKIES



A Historical Retrospect:
Rocky Mountain Hydraulic Laboratory
and the
Rocky Mountain Hydrologic Research Center
Allenspark, Colorado

January 1996

Colorado Water Resources Research Institute
Special Report No. 11

WATER RESEARCH IN THE ROCKIES

A Historical Retrospect:
Rocky Mountain Hydraulic Laboratory
and the
Rocky Mountain Hydrologic Research Center
Allenspark, Colorado

Special Report No. 11

January 1996

"Water Research in the Rockies" was prepared for the Rocky Mountain Hydrologic Research Center by the Colorado Water Resources Research Institute, with research and writing by Jill Marsh. The current president of the RMHRC, Marshall Flug, developed funding support for this effort, provided direction and technical support, and guided the report from its inception.

This publication was financed in part by the U.S. Geological Survey and the Colorado Water Resources Research Institute.

COLORADO WATER RESOURCES RESEARCH INSTITUTE
Colorado State University
Fort Collins, Colorado 80523
Robert C. Ward, Director

TABLE OF CONTENTS

Purpose of The Rocky Mountain Hydraulic Laboratory:

In the 1940s the field of hydraulic engineering included basic experiments in hydraulics and fluvial processes. The early researchers were working on the fundamentals that following generations of hydraulic researchers have built upon: how water flows, how to measure the flow, and what happens to a channel bank as the flow winds through the channel. Topics such as evaporation, the direction of flow into wells, seepage losses, and canal linings also were being explored.

With research as its focus, the Rocky Mountain Hydraulic Laboratory (RMHL) was created "To establish and maintain facilities for the conduct of scientific experiments in hydraulics and related fields, to foster the carrying out of such experiments, and to inform the engineering profession of the results of the investigations undertaken." The laboratory was to offer experience to young engineers interested in learning the techniques of hydraulic research. In addition to the experimental work, the laboratory was to schedule lectures by well-known authorities to provide an opportunity for the exchange of information between researchers. Although the laboratory's primary purpose was to facilitate fundamental research in hydraulics and related sciences, its greatest ultimate value may be this by-product of bringing professors, instructors, and energetic graduate students together with experienced engineers from industry and from government service.

Formation of The Rocky Mountain Hydraulic Laboratory:

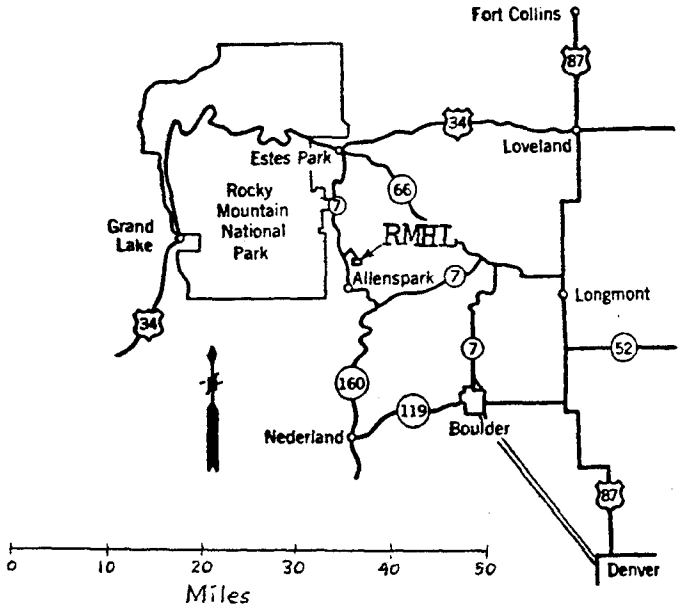
The Rocky Mountain Hydraulic Laboratory was organized under the laws of the State of Colorado on September 5, 1945. Unlike other hydraulic laboratories, it had no predecessor nor any sponsoring agency or institution to give it a start. In fact, the site itself suggested the laboratory. Chesley Posey, one of the founding fathers of the laboratory, found the site while hiking in the mountains south of Estes Park, Colorado in the early 1940s. Posey found a crystal-clear mountain stream, fed by melting snow, that dropped steeply in a sheltered valley. A series of gently sloping shelves on one side of the stream offered ample working area for flumes, while an elongated hillock was ideally shaped for a constant head tank to supply perhaps as many as a dozen experimental setups, each with an independent intake. The North St. Vrain Creek had a fall of nearly eighty feet in a quarter of a mile, and could easily be diverted to supply each of the working areas. Its flow, which is well over 100 cubic-feet per second (cfs) early in the summer, seldom dwindles to less than 30 cfs before the middle of September. It looked like an ideal place for an outdoor summer laboratory.

Chesley Posey

A few years after Posey found the site he showed it to Gerard H. Matthes and Emory W. Lane, who were in Denver attending an American Society of Civil Engineers meeting. Both men had extensive experience with hydraulic laboratories and were impressed by the site, and agreed that a hydraulic lab should be built. Matthes, principal engineer of the U.S. Waterways Experiment Station at Vicksburg, Mississippi, had visited many European laboratories and said the area was the best natural site he had ever seen.

There was, however, one major difficulty. The site was part of a 150-acre fox farm and the owners were not interested in selling the 20-acre site along the creek. However, in the early spring of 1944 Posey received word that the fox farm operation had been abandoned and that the entire acreage was for sale. Francis Dawson, a professor of hydraulic engineering and future president of RMHL, entered into a partnership with Posey and the two men bought the farm. The 20-acre site along the creek, which was to become the RMHL, was donated to a nonprofit corporation that was to be established to own and operate the laboratory.

Initially, there was legal trouble in clearing title to the site. The area had been used a generation earlier to generate electricity for gold-mining operations near Allenspark. A head flume on the steep bank, portions of a penstock, and a partially washed-out power house foundation still existed. However, since there was no longer any mining activity in the area, the almost-forgotten title was finally cleared.



Site of Rocky Mountain Hydraulic Laboratory

In planning for the nonprofit corporation, the histories of similar enterprises, particularly the Oceanographic Institute at Woods Hole, Massachusetts, were

Seventh Annual Meeting - August 16, 1952. *Left to Right, standing - Richard Pugh, P. C. Benedict, J. E. Steele, H. M. Fitch, Francis Bell, Ralph Powell, Maurice Albertson, D. C. Bondurant, Warren DeLapp, Edgar Foster, Emory Lane, Ralph Goodrich, Frank Kerekes. In front - George Nordley, James Chinn, Robert Thomas, Thomas Evans, and Larry Shaw*

studied. Henry J. McAllister contributed advice in drawing up the Articles of Incorporation which were filed with the Secretary of the State of Colorado on September 5, 1945. Later on, with the assistance of Judge Clifford Stone, federal and state tax exemption was obtained.

A unique feature of the corporation was that members of the hydraulics divisions or sections of certain national organizations, such as the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Geophysical Union, were automatically qualified to become RMHL members.

During the period of organization, some of the most distinguished hydraulic engineers in the country were recruited to serve as trustees. The 12 trustees named in the Articles of Incorporation were Hardy Cross, Francis Dawson, Ivan Houk, Gerard Matthes, Adolph Meyer, Chesley Posey, John Savage, Edward Soucek, Jack C. Stevens, Clifford Stone, Royce Tipton and Sherman Woodward.

Over the years, other prominent hydraulic engineers, such as Emory Lane, Ralph Goodrich, Ralph Powell, Ralph Parshall, Harold Martin, Maurice Albertson, Francis Bell, and Carl Izzard have served as trustees as well. The laboratory's first President was Gerard Matthes; the Secretary was Professor Ralph Powell; and Chesley Posey served as Director and Treasurer. In August of 1946, counting the 12 Board members, the Laboratory had 25 members, including one from Sweden, two from South America, and one from Canada.

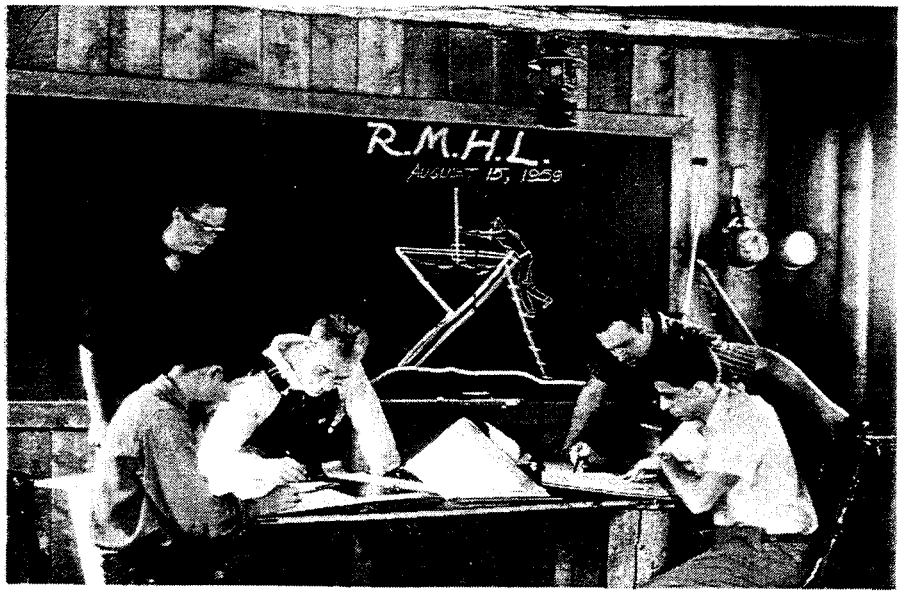
RMHL Shop Building

Because of the war, not much could be accomplished at the site until 1946, when the north entry road was improved and a timber and concrete shop building with 720 sq. feet was built using donated labor and borrowed funds.

That first summer a course on open-channel flow was given at the laboratory which carried graduate credit at the University of Iowa. During that time, Gerard Matthes found a large deposit of fine sand suitable for erosion testing on the property and suggested that the first project be an investigation of scour around bridge piers.

During the following summer, Emory Lane and Chesley Posey selected a site for an erosion flume. A wooden flume 6 feet wide and 18 feet long was built and experiments were begun.

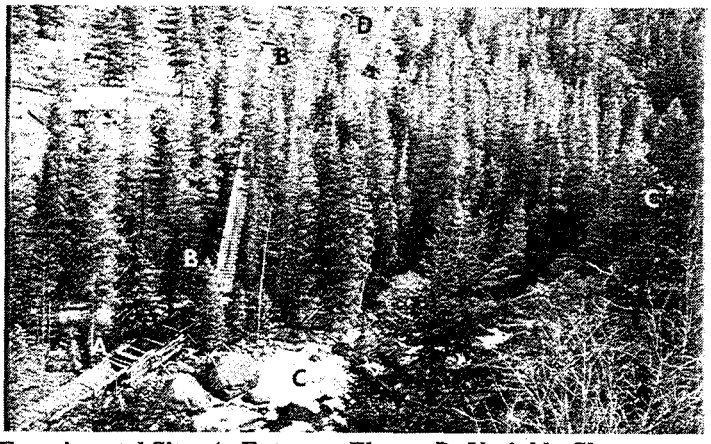
A series of preliminary tests of scour around bridge piers was also undertaken with the assistance of Professor David Appel, then a graduate student at the State University of Iowa, and a group of five graduate students from the Philippines. This led to a contract for tests of erosion protection from the U.S. Bureau of Public Roads, and eventually, in later summers, from the Bethlehem Steel Company and the Standard Oil Company of Texas, through the California Research Corporation. These contracts provided for overhead which enabled the laboratory to meet expenses.



RMHL Students with Chesley Posey, Summer 1959

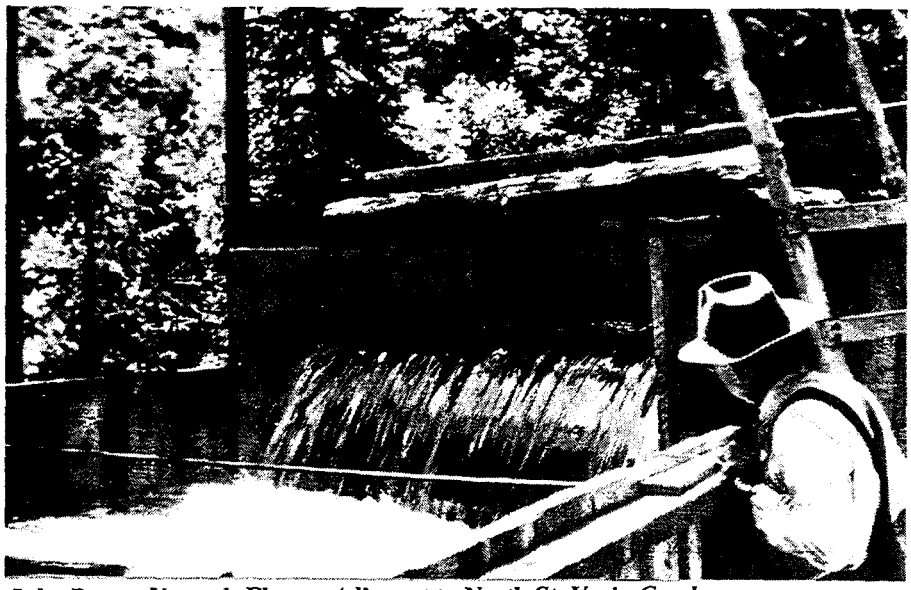
FACILITIES

The laboratory was designed to serve a unique function for which the location at Allenspark was ideal. Although the type of work undertaken at the RMHL had slender financial support, it was hoped that the low cost of operation, made possible by working outside with a gravity water supply, would enable the lab to investigate a number of questions.



Experimental Site: A- Entrance Flume, B- Variable-Slope Flume, C- St. Vrain Creek, D- Shop

The site itself is a 20-acre rectangle about 3/4 of a mile east of the St. Vrain Forest Highway bridge across the North St. Vrain Creek. Six miles to the west is the Continental Divide, and there are many permanent snow banks and lakes feeding the small streams which join to form the North St. Vrain Creek. The drainage area of the Creek, which is above the site, is 33 sq. miles.


Inlet Box to V-notch Flume, Adjacent to North St. Vrain Creek

The elevations within the drainage area vary from 8,000 feet above sea level at the lab site to 14,255 feet at the top of Longs Peak.

Because the elevation of the site is high, intense rainfall is rare and discharge in most of the streams, which comes from melting snows, is remarkably uniform. The region offered unusual opportunities for the study of stream morphology because of the constant discharge, the absence of the complicating factor of floods, and the range of stream sizes and slopes that were available.

Early Research Conducted:

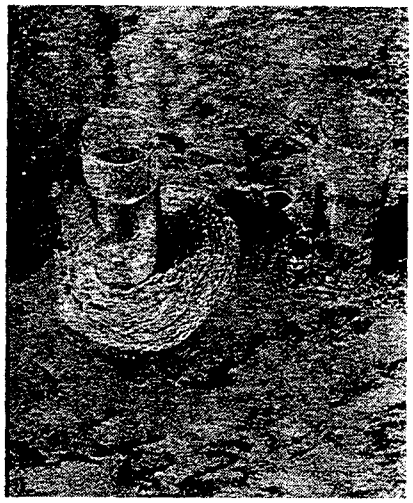
Research always was the primary focus of the Rocky Mountain Hydraulic Laboratory. During the laboratory's second summer of operation in 1947 a movable bed flume and a bridge pier model were built so that research could begin.

Over the years countless experiments have been conducted on numerous topics, but the three most prevalent areas of study were scour, open channel hydraulics, and hydraulic drops.

SCOUR

In the summer of 1948 the laboratory began experiments on scour with a trial series of runs in the six-foot flume using a new method of testing suggested by Gerard Matthes. His inventive idea was to use a hollow and transparent pier so that the depth of scour readings could be taken inside the pier while the apparatus was being run. This avoided the changes that ordinarily occurred when the discharge was shut off and the model was unwatered to permit direct measurements of the scour depth.

The "pier" was a one-liter glass graduate with observations made with the aid of a small mirror mounted at a 45-degree angle on the end of a wire handle. The crystal clear water at the laboratory made it an ideal place to try the new method.



Taking scour readings

The new method proved to be even better than had been anticipated. Measurements were taken not only of the depth of scour around the pier, but the researchers, who included Matthes, Emory Lane, Ralph Powell, and Chesley Posey, also measured the general level of the stream bed away from the pier. Observations of vortexes, kolk action (scour), and the movement of sand particles were made with ease. The researchers, using the new method, discovered that the movement of sand picked up by the vortex was in a downward motion next to the model pier.

During the summer of 1949 the laboratory began conducting experiments to find ways of protecting existing bridge piers from erosion. Several schemes were eliminated, and the research results indicated that a flexible mat placed around the bridge pier was effective in reducing the depth of scour.

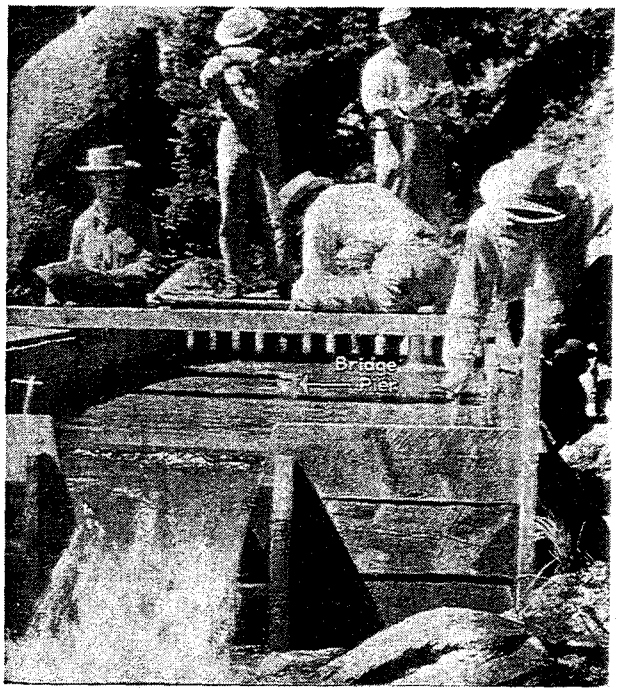
The flexible mat that was used was made of link-chain wound about the pier in a spiral one layer thick and held by radial cords, 9 inches in external diameter. On the downstream side of the pier the mat prevented

any scour below the average bed level, and on the upstream side the scour was greatly reduced.

The researchers also discovered that where a flexible mat prevented scour, a stiff, impervious mat provided no protection once the scour got beneath the edges of the mat. This research led to a contract in the summer of 1950, between the Laboratory and the Bureau of Public Roads of the Department of Commerce, to conduct research and obtain data to be used in developing a design criterion for flexible mats which were to be placed around bridge piers.

These experiments led to several more contracts for the laboratory. In the summer of 1952 the RMHL conducted research for the Shipbuilding Division of Bethlehem Steel Company on protection against scour under drilling barges and underwater oil tanks.

In 1953 the laboratory performed erosion experiments in connection with an investigation for the Iowa Highway Department. Again in 1959 experiments on scour protection were conducted under a contract with Standard Oil Company of Texas and the California Research Corporation. For over a decade, the laboratory's innovative research on scour and scour protection provided contracts and funding for the RMHL.



RMHL Conducted Innovative Research on Scour

OPEN CHANNEL HYDRAULICS

A second major area of research for the laboratory was open channel hydraulics. From the time the laboratory site had been discovered the possibility of building a long variable-slope flume had been considered. During the winter of 1953-54 a proposal for building the flume and conducting research on open-channel friction was prepared jointly by the RMHL and Colorado State University and submitted to the National Science Foundation.

A 400-foot flume was constructed which could cover a range of slopes from about 0.0004 to 0.015, depths from 0.25 to 2.5 feet, and discharges from 0.01 to 35 cubic feet per second. Both batten-type roughnesses and natural-type roughness were tested, as well as smooth painted surfaces. The laboratory continued experiments in the flume through 1957 in cooperation with Colorado State University with assistance from the United

States Geological Survey, the State University of Iowa, and Ohio State University.

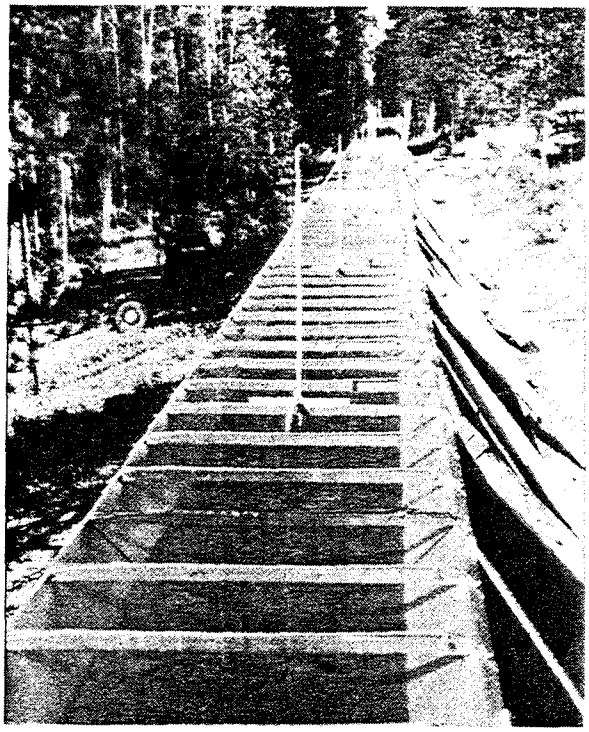
In 1958 the RMHL received a two-year grant from the National Science Foundation to continue to investigate, in cooperation with the USGS, friction loss for water flowing in a long open channel over a wide range of depths and slopes.

In the first series of tests, the surface of the flume was smoothly-painted plywood.

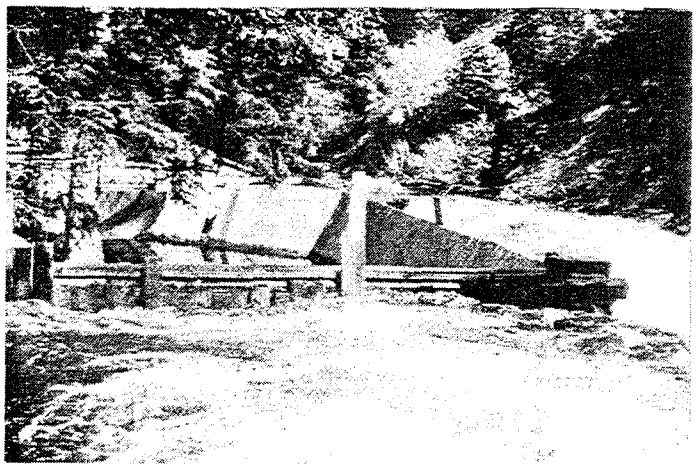
For the second series, rectangular battens were nailed to the plywood to form an artificial roughness, and various combinations of batten spacing, slope, and depth of flow were tested.

In the third series of tests, the inside of the flume was coated with a one-fourth inch thickness of paraffin wax, into which various natural-type roughnesses were rolled. The roughness could be easily changed and a given roughness could be closely duplicated at will.

Until this time, not much had been accomplished in solving the problem of the evaluation of the hydraulic roughness of natural surfaces. The tests conducted at the laboratory on rough-surface evaluation were unique because they provided a reliable and economical method of testing various friction coefficients in a region of uniform flow.



Open Channel Flow in the Variable Slope Flume



Headgate of entrance flume in North St. Vrain Creek

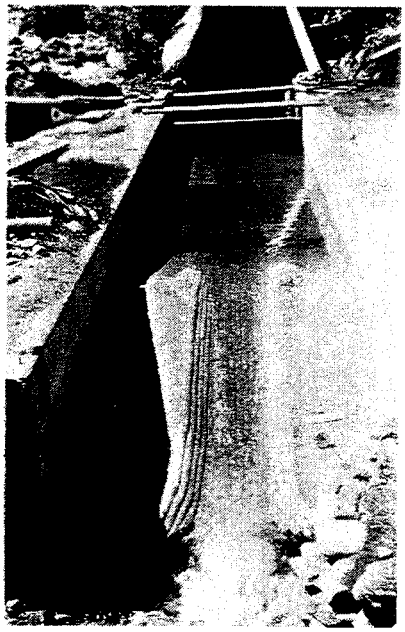
In a second phase of the research, horizontal bottoms of one-half foot, one-foot, and two-foot widths were installed, giving a series of geometrically similar trapezoidal channels which were tested in the same manner as a triangular section.

Research on open channel hydraulics continued through the 1960s, including the experiments on channel stabilization in the summer of 1966, until 1968 when the flume was finally dismantled and salvaged. In all, more than

220 uniform-flow experiments were conducted using the flume. Because it was built as cheaply as possible, the flume was not as perfect as could be desired, but the data that it produced provided information on what had to be done to build a more accurate and easily used flume.

HYDRAULIC DROPS

Another major area of research at the laboratory concerned hydraulic drops. In the summer of 1953 the laboratory began erosion control testing using rock sausages. Rock sausages are built by enclosing rocks in cylindrical cages. These cylinders of caged rock are used to line open channels with the intent of reducing channel erosion.



A sausage-protected spillway under test

Research was done on the construction necessary for the effective utilization of rock sausages, such as the size of mesh, diameter of the sausage, and the amount of flow that it could resist. Rock sausages were not as heavy and rigid as gabions and could be made of wire tubing, making them lighter and able to lie in a channel. Their flexibility gave them the ability to adjust if the pressure changed.

During the 1970s this area of research continued as the laboratory worked on hydraulic drop designs with better erosion control. In the summer of 1982 the lab installed demonstration ditches in the Boulder-Longmont area using rock sausages to help control erosion. Unfortunately, however, it was during this time period that the laboratory began to decline and research activities began to dwindle considerably.

Recent Developments:

The RMHL reached its peak during its first 15 years. Research contracts and activities increased during this time, as well as the number of faculty and students using the facility. Then, about 1960, the laboratory's activity declined. There was a ten-year period during the late 1970s and early 1980s that William Moeller, a professor in hydraulics and a RMHL president, has called "The years of silence." The laboratory site was seldom used during this time, with less students and no leading research being done. Part of the explanation for the decline was the competition from high-tech hydraulic research at university laboratories. Hydraulic research was utilizing more sophisticated instrumentation and

becoming more technical, and the RMHL could not compete for research projects or student participation. The RMHL tried to revive the laboratory by broadening it's scope and joining in a partnership with the United States Geological Survey (USGS).

PARTNERSHIP WITH THE USGS

In 1984 the Trustees began discussing the future of the laboratory. These discussions were undertaken primarily for three reasons: 1) the laboratory had not been very active over the past few years, 2) most of the work associated with the finances, maintenance, and housekeeping of the laboratory had been shouldered by Posey for many years and it was time to consider passing the duties on to someone else, and 3) there was disagreement over the use and goals of the laboratory.

The two options mentioned were to either disband or continue the operations of the RMHL. At a meeting on August 11, 1984, the Trustees discussed disbandment, but voted to continue operating. They then considered the option that the continuation of the laboratory would be enhanced if an outside group were to participate in the facility's activities.

The US Geological Survey was mentioned as one possibility. Discussion had been held with the USGS in 1978 on this matter, but nothing ever came of it. A committee of three trustees was appointed to investigate, with representatives of the USGS, their participation and collaboration. At this time, the RMHL was considering having the USGS take over the laboratory in two or three years.

On November 1, 1985, the RMHL entered into an agreement with the US Geological Survey. Under the conditions of the agreement, the USGS was to assume full responsibility for the operation and maintenance of the laboratory, but the RMHL Board of Trustees was to serve as advisers on matters of policy.

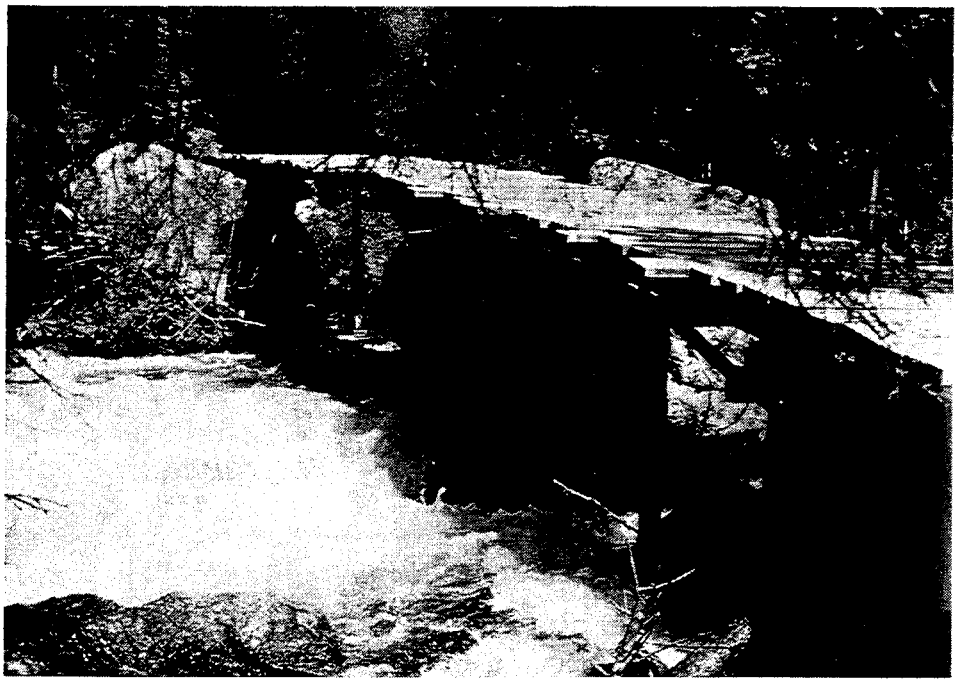
The USGS chose to take part in the laboratory because of its proximity to the Denver Federal Center and the USGS Central Region Water Resources Division/National Research Program, which was headquartered in Denver. The location made the RMHL watershed and stream a near-ideal location for research, and the USGS desired to conduct interdisciplinary research at the RMHL for a period of three to five years. The research would include hydraulics of flow in high-gradient mountain streams; snowmelt runoff; performance of hydrologic instrumentation at high altitudes; stream biology; and water-quality characterization of the basin.

NAME CHANGE

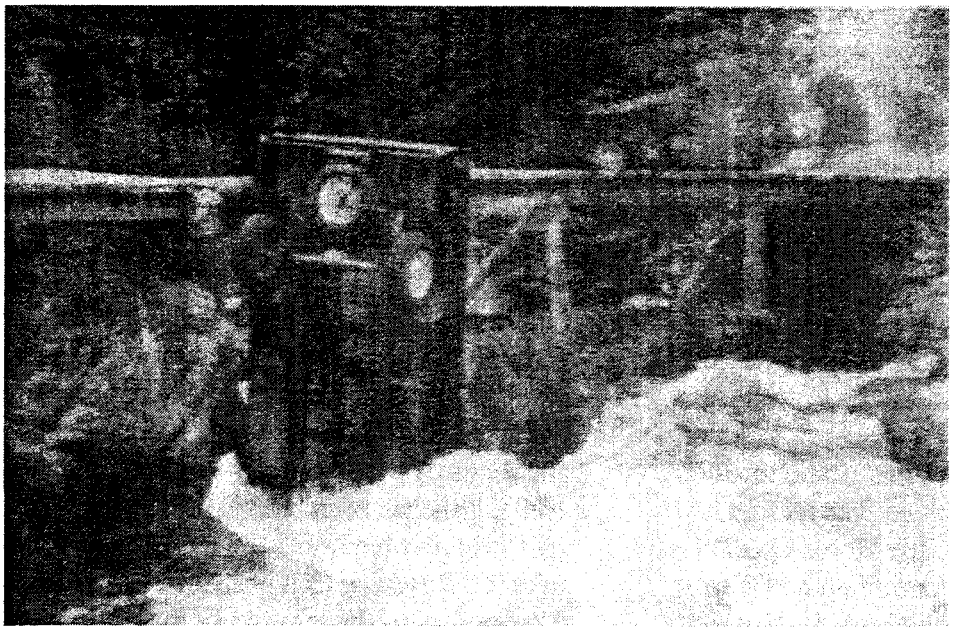
The Rocky Mountain Hydraulic Laboratory underwent another change in 1991 when its name was changed to the Rocky Mountain Hydrologic Research Center. This name change reflected the organization's capability of conducting a broad range of hydrologic and environmental science investigations in headwater areas of the Rocky Mountains.

PRESENT STATUS

In celebration of the 50th Anniversary Annual Meeting, a two-day technical program was held at the YMCA Camp of the Rockies in Estes Park, Colorado, on September 22-23, 1995. The technical program theme was "The Next 50 Years: Stream Ecology, Ecosystems and Watershed Interactions."



Access bridge across St. Vrain River



Chesley Posey Drives His Truck Across Bridge and Into the North St. Vrain Creek, 1969.

The RMHRC continues to hold these annual meetings, publish at least abstracts of papers presented, and support field research at or near the RMHL. Current research includes geomorphological, biological, ecological, and water quality studies along the North St. Vrain Creek and Little Horse Creek adjoining the laboratory.

Plans for the 51st Annual Meeting

are underway and call for another two-day format focussing on "Ecological Issues in Mountain Watersheds."

From the beginning, access to the laboratory site has been a problem. The Research Center is actively pursuing this issue as it has a direct effect on the future of the laboratory site.

In 1989 the laboratory began looking into an alternate access road, as the old one had sharp turns, was narrow, and the bridge had become questionable for supporting cars and trucks.

The RMHRC continues to address the question of access, and has explored numerous options and had discussions with several adjoining landowners in an attempt to find a solution agreeable to all concerned. At the present time there are three options available to the RMHRC: access from the north, the northwest, or the south.

The Future:

The Rocky Mountain Hydraulic Laboratory was formed during an earlier, simpler time when, to conduct hydraulic research, one could take a stream, divert it by throwing more stones in, and build a concrete flume. There was no electronic equipment or instrumentation, and research could be done by using a shovel, observing the stream, and recording measurements.

Sampling for benthic invertebrates, Robert C. Averett

Although the needs of research have changed, there continues to be a need for the basic types of research the laboratory can provide. The laboratory site is a resource that can be used for a variety of research, from water-quality and sediment-transport studies to ecological and terrestrial-aquatic studies.

The site is situated in a prime location to do long-term studies on ecological and biological issues as the Little Horse Creek, which contains some mountain home effluent input and seepage, and the North St. Vrain Creek, which flows out of Rocky Mountain National Park and is fairly pristine, both run through the property. The laboratory needs to respond to the changes and new opportunities for research. As researchers' insights change, the focus of the laboratory needs to change as well. This has been, and is being, recognized by those involved with the laboratory as they take the Research Center in a new direction. The vitality of the laboratory in the future will depend on the vitality of those who use it.

The Rocky Mountain Hydraulic Laboratory and the Rocky Mountain Hydrologic Research Center have undergone many changes over the years. But even as hydraulics and hydrologic research has changed and expanded over time, the laboratory provides a unique location and conditions that allow researchers to conduct basic resource studies in a natural setting with a minimum amount of restrictions. The laboratory can, and will, continue to play an important and vital part in natural resources research as long at it can respond and adapt to the ever changing needs of hydrologic research.

APPENDIX I

ARTICLES OF INCORPORATION

Incorporated September 5, 1945

ARTICLE I

The corporate name and title by which said corporation shall be known in law, is Rocky Mountain Hydraulic Laboratory.

ARTICLE II

The particular business and objects for which this corporation is formed are:

1. To establish and maintain facilities for the conduct of scientific experiments in hydraulics and related fields, to foster the carrying out of such experiments, and to inform the engineering profession of the results of the investigations undertaken.

2. To receive and maintain a fund or funds and to apply the principal and interest thereof or any other property of the corporation to such scientific purposes exclusively as will, in the absolute and uncontrolled discretion of the Trustees, most effectively assist, encourage and promote said purposes.

3. To take and hold gifts from individuals, firms or associations, or from the Federal or State governments or their agencies, either absolute or in trust for any of its purposes, and while the owner thereof to exercise and enjoy all of the rights, powers and privileges of ownership to the same extent as a natural person might or could do; to operate, use, enjoy, assign, sell, transfer, convey or otherwise dispose of any such property; to invest and reinvest its funds, either principal or income, in any securities or property of whatsoever character deemed proper by its Trustees for such investment; to employ, donate and expend the property and funds of the corporation; but always for the purposes thereof as specified in the preceding paragraph of this Article II.

4. To make, enter into and perform contracts of every kind and description, necessary, advisable or expedient in carrying out the purposes of the corporation, with any person, firm, association, corporation, municipality, body politic, county, state or government.

5. To have one or more offices and to conduct and carry on any of its business at any place in the State of Colorado as may be determined by its Trustees; but unless and until otherwise determined, the principal office shall by kept at Allenspark, Boulder County, Colorado.

6. Without limitation of the foregoing, to have and exercise all of the rights, powers and privileges specified in 1935 Colorado Statutes Annotated, Chapter 41, Article 13, Section 174.

ARTICLE III

The corporation shall have perpetual existence.

ARTICLE IV

The number of Trustees who shall conduct and manage the business and affairs of said corporation shall be twelve, and the names of the Trustees selected for the first year of the existence of the corporation are Hardy Cross, Francis M. Dawson, Ivan E. Houk, Gerard Matthes, Adolph F. Meyer, Chesley J. Posey, John L. Savage, Edward Soucek, J.C. Stevens, Clifford H. Stone, Royce J. Tipton, and Sherman M. Woodward.

ARTICLE V

No member, Trustee, officer or employee of the corporation shall receive or be lawfully entitled to receive any pecuniary profit from the corporation or its operations, except reasonable compensation for services in effecting one or more of its purposes.

ARTICLE VI

Qualifications for membership in the corporation shall be set forth in its By-Laws which shall describe the powers and duties of the Trustees and officers of the corporation, and the Trustees of the Corporation shall have the power, from time to time, to make, alter and amend such prudential By-Laws as they shall deem proper for the management of the business and affairs of said corporation.

BY-LAWS
(1945)

ARTICLE I

Any member in good standing of the hydraulics sections or divisions of the American Society of Civil Engineers, the American Society of Mechanical Engineers, or the Society for the Promotion of Engineering Education shall, if he desires, be considered to be a member of the corporation, and entitled to all the privileges of membership including the right to attend meetings and that of joining with other members in making nominations for Trustees.

ARTICLE II

Annual Meetings of the corporation shall be held in August. The order of business, unless otherwise provided by the Trustees, shall be as follows: report of the Trustees, report of the Director, report of the Secretary, report of the Treasurer, new business.

ARTICLE III

1. Annual meetings of the Trustees shall be held the third Saturday in August, at Allenspark, Colorado. Special meetings may be held at such times and places as may be determined by the officers; provided, however, that two weeks notice of such special meetings shall be sent by registered mail to all Trustees; and provided further that the officers shall call a special meeting upon the written request of three Trustees. At any meeting of the Trustees three shall constitute a quorum for all purposes.

2. The Terms of Office of Trustees shall be six years, with four Trustees elected each two years. The terms of office of the first Trustees shall be as follows:

1945-1947	1945-1949	1945-1951
Gerard Matthes	Hardy Cross	Francis M. Dawson
Adolph F. Meyer	John L. Savage	Ivan E. Houk
Clifford H. Stone	J.C. Stevens	Chesley J. Posey
Sherman M. Woodward	Royce J. Tipton	Edward Soucek

3. Election of Trustees for new terms, or to fill vacancies, shall be by two-thirds vote of the Trustees present and voting. Nominations may be presented to the Trustees by petition signed by twenty members of the corporation.

ARTICLE IV

The Trustees shall elect from their membership a president whose duties shall include presiding at meetings of the Trustees and of the corporation. The Trustees shall also elect a secretary, a treasurer, and a director. The director shall be the executive officer for the coordination of experimental investigations and shall exercise, at times when the Trustees are not in session, such part of the authority of the Trustees as may be delegated to him.

ARTICLE V

These By-Laws may be amended at any meeting of the Trustees by a two-thirds vote of the Trustees present and voting, providing that at least one month's notice of the proposed change be given to all of the Trustees.

Over the years, the By-Laws have been amended several times. Following are the By-Law amendments and the approval dates.

1947 In Article I, the words "or the Society for the Promotion of Engineering Education" are stricken out, and in their stead are inserted the words "The American Society for Engineering Education, or the American Geophysical Union".

1960 In pursuance of Article II of our By-Laws, the order of business for the Annual Meeting shall be as follows: reading of the minutes of the previous meeting, report of the Trustees, report of the Director, report of the Treasurer, new business.

1962 Article III changed to read "Annual meetings of the Trustees shall be held the second Saturday in August --".

1973 Second sentence of Article IV was changed to read "The Trustees shall also elect a Secretary, Treasurer, Vice President, and Director. The Vice President is to act as the President in the absence of the President."

Two new Articles to the By-Laws were proposed and accepted on August 11, 1984; they are:

ARTICLE VI

Any proposal for research at the Rocky Mountain Hydraulic Laboratory, Inc. Involving expenditures of more than $10,000 per year shall be approved by two-thirds of the Trustees.

ARTICLE VII

Any contracts or agreements with universities, governmental agencies, or nonprofit groups to operate the Rocky Mountain Hydraulic Laboratory, Inc. must be approved by two-thirds of the Trustees.

ARTICLES OF AMENDMENT
TO THE
ARTICLES OF INCORPORATION
AND
RESTATEMENT OF THE ARTICLES OF INCORPORATION
(Adopted January 27, 1992)

Pursuant to the provisions of the Colorado Nonprofit Corporation Code, the undersigned corporation adopts the following Articles of Amendment to its Articles of Incorporation and restates its Articles of Incorporation.

FIRST: The name of the Corporation is ROCKY MOUNTAIN HYDRAULIC LABORATORY.

SECOND: The following amendments and restatement were adopted by the directors of the Corporation on January 27, 1992, in the manner prescribed by the Colorado Nonprofit Corporation Code. The restated Articles of Incorporation supersede the original articles and all amendments thereto. The original filing date of the Articles of Incorporation was September 5, 1945.

ARTICLE 1

Name

The corporate name of the Corporation shall be:
ROCKY MOUNTAIN HYDROLOGIC RESEARCH CENTER

ARTICLE 2

Duration

The existence of the Corporation shall be perpetual.

ARTICLE 3

Registered Office and Agent

The address of the registered office of the Corporation is 420 S. Howes Street, Suite 200, Fort Collins, Colorado 80521, and the name of its registered agent at such address is Kenneth C. Wolfe.

ARTICLE 4

Purposes and Powers

Clause (a) General. To establish and maintain facilities for the conduct of scientific experiments in hydraulics and related fields, to foster the carrying out of such experiments, and to inform the engineering profession of the results of the investigations undertaken.

Clause (b) Ancillary Purposes. The Corporation shall have and may exercise all of the rights, powers and privileges now or hereafter conferred upon nonprofit corporations organized under the laws of Colorado. In addition, the Corporation may do everything necessary, suitable or proper for the accomplishment of any of its purposes. The Corporation may conduct part or all of its business in Colorado, other states of the United States or the world and may hold, purchase, mortgage, lease and convey real and personal property in any of such places.

ARTICLE 5

Capital

There shall be no capital stock of the Corporation. The rights of the membership to vote shall be set forth in the By-laws of the Corporation.

ARTICLE 6

Provisions for Regulation of The Internal Affairs of the Corporation

Section 6.01. By-laws. The initial By-laws shall be adopted by the Board of Directors. The power to alter, amend, or repeal the By-laws or to adopt new By-laws shall be vested in the Board of Directors. The By-laws may contain any provisions for the regulation and management of the affairs of the Corporation not inconsistent with the Code of these Articles of Incorporation.

Section 6.02. Compensation. No part of the earnings of the Corporation shall inure to the benefit of, or be distributable to, its members, directors, officers, or other private persons, except that the Corporation shall be authorized and empowered to pay reasonable compensation for services rendered and to make payments and distributions in furtherance of the purposes set forth in Article 4 hereof. No substantial part of the activities of the Corporation shall be the carrying on of propaganda, or otherwise attempting to influence legislation, and the Corporation shall not participate in, or intervene in (including the publishing or distribution of statements) any political campaign on behalf of any candidate for public office. Notwithstanding any other provision of these Articles, the Corporation shall not carry on any other activities not permitted

to be carried on (a) by corporations exempt from federal income tax under Section 501 © (3) or Section 501 © (7) of the Code or (b) by a corporation, contributions to which are deductible under Section 170 © (2) of the Code.

Section 6.03. Elimination of Certain Liability of Directors. A director of the Corporation shall not be personally liable to the Corporation or its shareholders for monetary damages for breach of fiduciary duty as a director, except for liability (I) for any breach of the director's duty of loyalty to the Corporation or its shareholders, (ii) for acts or omissions not in good faith or which involve intentional misconduct or a knowing violation of law, (iii) under the Colorado Corporation Code, or (iv) for any transaction from which the director derived an improper personal benefit.

Section 6.04. Dissolution. Upon dissolution of the Corporation, the Board of Directors shall, after paying or making provision for the payment of all of the liabilities of the Corporation, dispose of all of the assets of the Corporation by donating such assets to the College of Engineering, Civil Engineering Department, Colorado State University, Fort Collins, Colorado.

ARTICLE 7

Data Respecting Directors

Section 7.01. Board of Directors. The Board of Directors shall not be required to be residents of the state of Colorado. The term "Board of Directors" shall mean the governing body of the facility and need not be titled "Board of Directors" but may be referred to as "Board of Trustees" or any similar title.

Section 7.02. Name and Address. The names and addresses of the persons who are to serve as directors until their successors have been elected and qualified, follow:

Maurice L. Albertson	731 W. Olive Fort Collins, CO 80521
Robert C. Averett	1409 Rockmont Dr. Boulder, CO 80303
Charles William Boning	704 Tamani Dr. Herndon, VA 22070
George S. Clausen	Box 20516 Association Camp, CO 80511
Mike Donohue	Box 2062 Estes Park, CO 80517

Lyman R. Flook, Jr.	1694 Oneida St. Denver, CO 80220
Marshall Flug	1619 Centennial Rd. Fort Collins, CO 80525
Tissa H. Illangasekare	3867 Campo Ct. Boulder, CO 80301
Robert D. Jarrett	135 Balsam St. Lakewood, CO 80226
Herman J. Koloseus	1409 Brentwood Dr. Fort Collins, CO 80521
William M. Lewis, Jr.	122 Ramaley, Campus Box 334 Boulder, CO 80309-0334
William B. Moeller	167 Hollis St. Dunstable, MA 01827
Mildred Posey	Atrium Village, No. 106 Hills, IA 52235
Thomas G. Sanders	2201 Apache Ct. Fort Collins, CO 80525
Verne Schneider	2269 Compass Point Ln. Reston, VA 22091

Section 7.03. Increase or Decrease of Directors. The number of directors may be increased or decreased from time to time by amendment of the By-laws; but no decrease shall have the effect of reducing such number below seven, nor shall the number be increased above fifteen.

THIRD: These Articles of Incorporation may be amended by an affirmative vote of two-thirds of the Board of Directors, excluding ex officio members.

These restated and amended articles correctly set forth the provisions of the Articles of Incorporation as amended, and they supersede the original Articles of Incorporation and all amendments thereto.

BY-LAWS OF

ROCKY MOUNTAIN HYDROLOGIC RESEARCH CENTER
ROCKY MOUNTAIN HYDRAULIC LABORATORY
(Adopted October 19, 1992)

ARTICLE I: NAME & PURPOSE

Section 1.1 **NAME:** The name of this organization is **ROCKY MOUNTAIN HYDROLOGIC RESEARCH CENTER,** herein referred to as **"RMHRC"**, and formerly known as **ROCKY MOUNTAIN HYDRAULIC LABORATORY**, also referred to as the **"RMHL"**.

Section 1.2 **PURPOSE:** The RMHRC was established to conduct scientific experiments in hydraulics, watershed and environmental sciences, hydrologic engineering, and related fields; to maintain facilities for the conduct of such research; to serve, educate, and inform the scientific and engineering profession and the public of results from studies and investigations undertaken. In addition the RMHRC provides a facility for instruction in the fields of environmental, watershed, and engineering sciences.

ARTICLE II: MEMBERSHIP

Section 2.1 **MEMBERSHIP:** Any person may be elected to membership upon approval of one's application by a majority of the Board of Trustees of RMHRC, herein also referred to as the Board.

Section 2.1.1: To remain a member in good standing, members shall be current in payment of their dues.

Section 2.2 **PRIVILEGES:** Members shall have the right to attend all meetings of the Membership and Board.

Section 2.3 **MEETINGS:** An annual meeting will be held for the purpose of reporting to the membership on recent activities, future plans, and will include a Financial Report and status of Trustees and Officers. Other items may be included as determined by the Trustees. This meeting will normally be held in conjunction with the Annual Technical Meeting; otherwise Members will be notified at least 14 days in advance of the actual meeting.

ARTICLE III: MEETINGS OF THE BOARD

Section 3.1 **MEETINGS:** The RMHRC will convene an annual meeting of the Board of Trustees. This meeting will include the election of members of the Board and the election of Officers; a

Financial report; an update of recent and planned events; and other items as determined by the Officers or Trustees of the Board. Members shall be notified of this meeting at least 14 days in advance of the actual meeting.

Section 3.1.1: Special meetings of the Board may be called by or at the request of the President or any two Trustees. Notice of any special meetings shall be given to all Trustees at least three days prior to the meeting.

Section 3.1.2: In the event of an emergency or when the Board can't meet, the Board of Trustees may be polled by telephone to waive the provision for notification of a special meeting; and under an emergency situation business will be conducted by telephone proxy. The President and Secretary shall be authorized to conduct such telephone polls.

Section 3.2 QUORUM: Fifty percent of the current Trustees of RMHRC Board shall constitute a quorum at all meetings, but no less than four Trustees.

Section 3.3 MANNER OF ACTING: Except as otherwise required by law, or by the Articles of Incorporation, or as specified in the By-Laws, the act of the majority of the voting Trustees present at a meeting at which a quorum is present shall be the act of the membership.

ARTICLE IV: NOMINATIONS & ELECTIONS

Section 4.1 NOMINATIONS: Nominations for vacancies on the Board of Trustees will be by endorsement of two Trustees, or by petition signed by twenty percent of the members of the corporation.

Section 4.2 ELECTIONS: Elections of Trustees to the Board will be determined by a majority of votes cast by the Trustees of the Board. Normally these elections will be conducted at the annual meeting, although vacancies can be filled at any meeting of the Board.

Section 4.3 TERMS OF OFFICE OF TRUSTEES OF THE BOARD: The normal terms of Trustees shall be for six years, with one-third of the Trustees elected every two years. Thereby the terms of the Trustees are staggered. Vacancies are filled for the remaining time of the original six year term.

Section 4.4 QUALIFICATIONS: Trustees of the Board and Officers may serve consecutive terms, with no restriction on reelection or reappointments.

ARTICLE V: OFFICERS

Section 5.1 OFFICERS: The Officers of RMHRC shall consist of: President; Vice-President; Secretary; Treasurer; and Executive Director, and Deputy Executive Director.

Section 5.1.1 Appointment of Officers: Officers are appointed, from among the Trustees of the Board (with the exception of the Executive Director and the Deputy Executive Director), by a majority of affirmative endorsements from the Trustees of the Board at an official Board meeting. Normally these appointments will be conducted at the annual meeting, although vacancies can be filled at any meeting of the Board.

Section 5.1.2 Terms of Office: The normal term of office for Officers shall begin immediately following the annual meeting, and shall extend for the period until the annual meeting in two more years.

Section 5.2 FUNCTIONS: The President and Secretary shall be empowered, and both signatures required, to sign all legal documents.

Section 5.2.1: The President shall preside over all meetings of the Officers, the Board, and of the general membership. In the President's absence this responsibility will transfer to another Officer in the following order: Vice-President; Secretary; Treasurer; a Trustee.

Section 5.2.2: The Executive Director shall be responsible for coordination of all activities of the RMHRC.

Section 5.3 RESPONSIBILITY: The Officers report to the Board of Trustees and are accountable to the Board.

ARTICLE VI: BOARD OF TRUSTEES

Section 6.1 BOARD OF TRUSTEES: The term "Board of Trustees" shall mean the governing body of the Corporation; and is also referred to as the Board. The term Trustee therefore is a member of the Board.

Section 6.2 TENURE: Trustees of the Board are elected for a six-year term, such that in any two-year period one-third of the Board are newly elected. There is no restriction on Board members serving consecutive terms.

Section 6.2.1: A two-thirds majority of the voting Board of Trustees will determine the specific number of Trustees elected and serving in a given year; between the specified minimum of seven, and maximum of fifteen as identified in the Amended Articles of Incorporation dated March 25, 1992. This action can occur merely be electing or by not filling vacancies that arise either by

expiration or by resignation.

Section 6.2.2: Initially and until changed by the Board of Trustees, the Board is composed of fifteen members.

Section 6.3 DUTIES: The Board of Trustees shall oversee the welfare of the RMHRC and direct the Officers.

Section 6.4 QUORUM: A majority of the members of the Board shall constitute a quorum, but not less than four.

Section 6.5 MANNER OF ACTING: Except as otherwise required by law, or by the Articles of Incorporation, or as specified in the By-Laws, the act of the majority of the directors present at a meeting at which a quorum is present shall be the act of the Board of Trustees.

Section 6.6 VACANCIES, RESIGNATIONS, & REMOVAL: In the event that the Board determines that a Trustee or Officer is not fulfilling their respective duties, that individual may be removed by a two-thirds majority of the Board members voting. Any vacancies created on the Board may be filled for the remainder of that term by a two-thirds majority of the Board members voting.

Section 6.7 COMMITTEES: The Officers or Trustees of the Board may appoint committees as necessary to fulfill the needs of the RMHRC.

Section 6.8 PERFORMANCE OF DUTIES: Any Member of the RMHRC who performs their duties as a Trustee, Officer, Member, or on any committee, in good faith, in a manner they reasonably believe to be in the best interest of the Corporation, and with such judgement as an ordinarily prudent person in a like position would use under similar circumstances, shall not have any liability by reason of being or having been a Member, Trustee, or Officer.

ARTICLE VII: FISCAL YEAR

Section 7.1 FISCAL YEAR: The Fiscal year shall begin on January 1 and end on December 31.

ARTICLE VIII: AMENDMENTS

Section 8.1 AMENDMENTS: Amendments to these By-Laws shall be initiated by any Trustee on the Board and must be presented to the Board for consideration at least ten days before taking action to adopt such amendments. Approval of amendments requires acceptance by two-thirds of the members of the Board of Trustees voting at a meeting after the ten-day waiting period.

Section 8.2 NOTICE: Notification must be given to all Trustees regarding the proposed By-Law

changes at least ten days prior to any meeting at which a vote is to be taken.

ARTICLE IX: EXPENDITURES & CONTRACTS

Section 9.1 **EXPENDITURES:** Any proposal for research or facility activities at the Rocky Mountain Hydrologic Research Center involving expenditures exceeding $10,000 shall require approval by two-thirds of the Trustees.

Section 9.2 **OPERATING EXPENSES:** The Treasurer is authorized to distribute RMHRC funds to cover normally expected operating expenses associated with meetings and RMHRC business. Expenses in excess of $500.00 shall require the approval of a majority of the Trustees.

Section 9.3 **CONTRACTS:** Any contracts or agreements with universities, governmental agencies, or nonprofit groups to operate the Rocky Mountain Hydrologic Research Center must be approved by two-thirds of the Trustees.

APPENDIX II

AGREEMENT TO USE
THE ROCKY MOUNTAIN HYDRAULIC LABORATORY

THIS AGREEMENT is entered into this first day of November, 1985, by and between the Board of Trustees of the Rocky Mountain Hydraulic Laboratory (RMHL), a non-profit research organization incorporated in the State of Colorado, and the United States Geological Survey (USGS) of the Department of the Interior. (Authority for this Agreement is contained in the annual appropriation under the title GEOLOGICAL SURVEY - SURVEYS, INVESTIGATIONS AND RESEARCH.)

W I T N E S S E T H

WHEREAS, the Corporation (RMHL) has under its ownership, control, and operation the laboratory known as the Rocky Mountain Hydraulic Laboratory located on North St. Vrain Creek near Allenspark, Colorado; and

WHEREAS, the RMHL and the 33 square miles of drainage area of the North St. Vrain Creek above the laboratory site provides a natural mountain environment for hydraulic research; and

WHEREAS, the proximity of the RMHL to the Denver Federal Center and the USGS Central Region Water Resources Division/National Research Program headquartered there make this particular watershed and stream a near ideal location for research; and

WHEREAS, the USGS desires to conduct interdisciplinary research at the RMHL for a period of 3 to 5 years to include hydraulics of flow in high-gradient mountain streams; snowmelt runoff; the performance of hydrologic instrumentation at high altitudes; stream biology; and water-quality characterization of the basin;

NOW THEREFORE, it is mutually agreed as follows:

1. The USGS will assume full responsibility for the operation and maintenance of the laboratory beginning November 1, 1985.

2. There will be no financial consideration for the rights and privileges granted herein.

3. The USGS will operate the laboratory under the existing by-laws and charter of the RMHL.

4. The property will be used as a laboratory to advance the sciences of water resources through research, education, and training.

5. Activities will not be undertaken by the USGS that will substantially disturb the natural mountain environment.

6. The Board of Trustees will be kept informed of the laboratory activities of the USGS and will serve as advisers on matters of policy of the RMHL.

7. This agreement shall become effective on the day and year first above written, and shall continue in full force and effect until terminated by the USGS or RMHL at any time on 30 days written notice.

8. No Member of or Delegate to Congress or Resident Commissioner after his election or appointment, either before or after he has qualified and during his continuance in office, and no officer, agent, or employee of the Government, shall be admitted to any share of the agreement, or to any benefit arising therefrom, but this provision shall not be constructed to extend to this agreement if made with a corporation for its general benefit.

9. The Corporation warrants that it has not employed any person to solicit or secure this contract upon any agreement for a commission, percentage, brokerage, or contingent fee. Breach of this warranty shall give the USGS the right to terminate the agreement.

IN WITNESS WHEREOF, the parties have caused these presents to be executed the day and year first above written.

ROCKY MOUNTAIN
HYDRAULIC LABORATORY:

Name /s/ William B. Moeller
President, RMHL

ADDRESS Hollis Street
Dunstable, MA 01827

UNITED STATES OF AMERICA
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY;

By /s/ Philip Cohen 10/24/85
Philip Cohen
Chief Hydrologist

APPROVED:

/s/ George A. Honold
George A. Honold
Management Officer, Central Region

APPENDIX III

OFFICERS

Presidents

Gerard Matthes	1945-1953
Emory W. Lane	1953-1956
Francis M. Dawson	1956-1963
Ralph W. Powell	1963-1974
Maurice L. Albertson	1974-1984, 1990-1994
William B. Moeller	1984-1990
Marshall Flug	1994-present

Executive Directors

Chesley J. Posey	1945-1984
Dr. Carl F. Nordin	1985-1987
Maurice L. Albertson	1987-1988 (Acting Director)
Verne Schneider	1988-1990
Charles William Boning	1990-1993

Vice-President

Maurice L. Albertson	1973-1974
Francis M. Bell	1974-1981
William B. Moeller	1981-1982
Lyman R. Flook, Jr.	1982-1984
George S. Clausen	1984-1994
William M. Lewis, Jr.	1994-present

Deputy Executive Director

Robert Jarrett	1988-present

Secretary

Ralph W. Powell	1945-1963
Herman J. Koloseus	1963-1984, 1989-1992
Dennis M. Morrow	1984-1989
Marshall Flug	1992-1994
John. F. Scott	1994-present

Treasurer

Chesley J. Posey	1945-1984
Dennis M. Morrow	1984-1988
Herman J. Koloseus	1988-1992
Thomas G. Sanders	1992-present

APPENDIX IV

TRUSTEES

Maurice L. Albertson	1955-present		
Robert C. Averett	1991-1993	Gordon Kruse	1987-1989
Francis M. Bell	1959-1981	Emory W. Lane	1947-1959
George S. Clausen	1979-1993	William M. Lewis, Jr.	1989-present
Hardy Cross	1945-1955	Harold M. Martin	1957-1963
S. Mark Davidson	1962-1967	Gerard Matthes	1945-1953
Francis M. Dawson	1945-1963	John S. McNown	1961-1973
Nolan J. Doesken	1993-present	Adolph F. Meyer	1945-1963
Mike Donahue	1991-present	Robert T. Milhous	1993-present
J. Ernest Flack	1962-1989	William B. Moeller	1976-1995
Lyman R. Flook, Jr.	1969-1993	Dennis M. Morrow	1983-1989
Marshall Flug	1987-present	Carl F. Nordin, Jr.	1983-1989
Donald K. Frevert	1991-present	Ralph L. Parshall	1955-1959
Ralph D. Goodrich	1953-1962	Margaret S. Petersen	1963-1987
Ivan E. Houk	1945-1957	R. Petersen	1992
Dr. Tissa H. Illangasekare	1989-1995	Dean F. Peterson	1963-1983
Carl F. Izzard	1960-1961	Chesley J. Posey	1945-1993
Robert D. Jarrett	1985-present	Ralph W. Powell	1953-1976
Herman J. Koloseus	1967-1985	Everett V. Richardson	1968-1979

A. R. Robinson	1962-1963
James F. Ruff	1993-present
Thomas G. Sanders	1987-present
John L. Savage	1945-1961
Verne Schneider	1990-present
John Scott	1993-present
Edward Soucek	1945-1963 1973-1989
D. Stevens	1992
J. C. Stevens	1945-1955
Clifford H. Stone	1945-1952
Royce J. Tipton	1945-1968
Charles A. Troendle	1993-present
Ellen E. Wohl	1989-1995
Sherman M. Woodward	1945-1947
V. M. Yevjevich	1963-1969
Chia-Shun Yih	1963-1987

Honorary Lifetime Trustee:
Chesley J. Posey

APPENDIX V

PUBLICATIONS

1. "The Rocky Mountain Hydraulic Laboratory", C.J. Posey. Reprinted from The Iowa Transit, May 1946.

2. "Unsteady Flow with Inflow", Henry J. Putman. RMHL, 1947.

3. "The Problem of Lake Tanganyika", E.J. Devroey. RMHL, 1948.

4. "Unsteady Flow in Open Channels", Henri J. Putman. Reprinted from Transactions, American Geophysical Union, April 1948.

4D. Discussion of the above paper, by Pin-Nam Lin. Reprinted from Transactions, American Geophysical Union, April 1948.

5. "Graphical Integration of Partial Differential Equations with special applications to Unsteady Flow in Open Channels", Junius Massau, translated by Henri J. Putman. RMHL, 1948.

5S. Supplement to the above, consisting of a translation of the portions omitted in the 1948 issue, together with a section from Massau's Lessons on Mechanics, translated by Henri J. Putman. RMHL, 1958.

6. "Vedernikov's Criterion for Ultra-Rapid Flow", Ralph W. Powell. Reprinted from Transactions, American Geophysical Union, December 1948.

6D. Discussion of the above paper, by V.V. Vedernikov and by Ralph W. Powell. Reprinted from Transactions, American Geophysical Union, August 1951.

7. "Why Bridges Fail in Floods", C.J. Posey. Reprinted from Civil Engineering, February 1949.

8. "Resistance to Flow in Smooth Channels", Ralph W. Powell. Reprinted from Transactions, American Geophysical Union, December 1949.

9. "Flexible Mats May Reduce Scour at Piers of Small Bridges", David W. Appel. Reprinted from Engineering News-Record, May 25, 1950.

10. "Resistance to Flow in Rough Channels", Ralph W. Powell. Reprinted from Transactions, American Geophysical Union, August 1950.

10D. Discussions of the above paper, by W.M. Owen, J. Th. Thijsse, J.F. Halsey, and R.W. Powell. Reprinted from Transactions, American Geophysical Union, August 1951.

11. "Investigation of Flexible Mats to Reduce Scour Around Bridge Piers", C.J. Posey, D.W. Appel, and E. Chamness, Jr. Research Report No. 13-B, Highway Research Board, April 1951.

12. "Numerical Analysis of Continuous Unsteady Flow in Open Channels", Pin-Nam Lin. Reprinted from Transactions, American Geophysical Union, April 1952.

12D. Discussions of the above paper, by J.C. Schofeld and by Pin-Nam Lin. Reprinted from Transactions, American Geophysical Union, October 1953.

13. "Tests of Erosion Around Submersible Oil-Storage and Well-Drilling Barges", C.J. Posey. RMHL, October 1952.

14. "Scour holes easily contoured for erosion experiments", C.J. Posey. Reprinted from Civil Engineering, June 1953.

15. "'Insurance' concept balances economic factors in culvert design", Ralph W. Powell. Reprinted from Civil Engineering, June 1953.

16. "Some Basic Requirements for Protection Against Erosion", C.J. Posey. Reprinted from Proceedings, Minnesota International Hydraulics Convention, September 1953.

17. "How Good is Flood Control?", Gerard H. Matthes. Reprinted from Engineering News-Record, November 8, 1951.

18. "Resistance to flow in smooth pipes found directly", Ralph W. Powell. Reprinted from Civil Engineering, November 1954.

19. "Quicksand at Fords", Gerard H. Matthes. Reprinted from The Military Engineer, February 1943, with addendum written August 1953.

20. "Tests of Erosion Around Models of Submerged Oil-Drilling Barges", C.J. Posey and R.G. Warnock. RMHL, November 1956.

21. "Tests of the Flow of Water in a Smooth V-shaped Flume", R.W. Powell and C.J. Posey. RMHL, June 1957.

21D. Discussion of the above paper by H.J. Putman. RMHL, 1957.

22. "Resistance Experiments in a Triangular Channel", Ralph W. Powell and Chesley J. Posey, Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, May 1959.

22C. Author's closing discussion of the above paper, Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, November 1960.

22D. Discussion of paper by H.A. Einstein and Huon Li, "Secondary Flows in Straight Channels", C.J. Posey and R.W. Powell. Reprinted from Journal of Geophysical Research, July 1959.

22E. Discussion of paper by R.D. Goodrich, with Singh's Tables fro Backwater Curves in Triangular Sections, C.J. Posey. Reprinted from Proceedings of the American Society of Civil Engineers, V. 87, No. HY1, January 1961.

23. "Model Tests of Riprap Scour Protection", by Nelson Sousa-Pinto, Jack H. Sybert, and Chesley J. Posey. RMHL, December 1959.

24. "History of Manning's Formula", Ralph W. Powell. Reprinted from Journal of Geophysical Research, April 1960.

24A. "Another Note on Manning's Formula", Ralph W. Powell. Reprinted from Journal of Geophysical Research, August 1962.

24D. Discussion of "Capacity Tests in Large Concrete-Lined Canals", by Ralph W. Powell. Reprinted, with corrections, from Journal of the Hydraulics Division, Proc. ASCE V. 92, No. HY1, January 1966, together with Powell's discussion of Asoka Pal's "A Study of Open Channel and Pipe Flow Equations in the Light of Manning's Formula", reprinted from Central Board of Irrigations & Power Journal, V. 23, No. 3, July 1966.

25. "Tests of Erosion Protection for Production Structures", C.J. Posey. RMHL, November 1960.

26. "Water-Surface Profiles and Velocity Distribution for Flow in a Long Uniform Channel", C.J. Posey and R.W. Powell. RMHL, April 1961.

27. "Flood-Erosion Protection for Highway Fills", C.J. Posey. Bulletin No. 13, Iowa Highway Research Board, December 1960. Includes Paper No. 2071, Transactions, American Society of Civil Engineers, Vol. 122, 1957.

28. "El Laboratorio de Hidraulica de 'Rocky Mountain'", Chesley J. Posey. Spanish translation by Ing. Francisco Oroxco Ochoa. Reprinted from Cience y Tenica, Revista del Centro Estudiantes de Ingenieria, Vol. 130, Julio-Agosto 1961.

29. "Erosion Protection of Production Structures", C.J. Posey and J.H. Sybert. Reprinted from Proceedings of the Ninth Convention, International Association for Hydraulic Research, Dubrovnik, 1961.

30. "Manning's Formula for Wide Trapezoidal Channels", C.J. Posey and S.N. Pagay. Reprinted from Civil Engineering, March 1963.

31. "Protection of Soil from Erosion by Swiftly Flowing Water", C.J. Posey. Reprinted from Proceedings of the Iowa Academy of Science, 1962.

32. "The Use and Misuse of Hydraulic Models", Ralph W. Powell. Reprinted from The Port Engineer. July 1955.

33. "Scour at bridge-piers - 2. Protection of threatened piers", C.J. Posey. From Civil Engineering, May 1963.

34. "Are Flood-Plain Regulations Sound?", C.J. Posey. From Civil Engineering, June 1965.

34D. Discussion of Environmental Effects of Flood Plain Regulations", C.J. Posey. Reprinted from Journal of the Hydraulics Division, Proc. ASCE, March 1966.

35. "Experiments with Buried Floats to Determine Depth of Scour", W.B. Moeller. RMHL, November 1965.

36. "Resistance Near the Energy Critical in Open Channel Flow", Chesley J. Posey. International Association for Hydraulic Research. XIth Congress, Leningrad, 1965.

37D. Discussion of "Errors in Piezometric Measurement", by C.J. Posey. Reprinted from Journal of the Hydraulics Division, Proc. ASCE, September 1965.

38. "Computation of Discharge Including Over-bank Flow", C.J. Posey. Reprinted from Civil Engineering, April 1967.

39. "Erosion Prevention Experiments", Chesley J. Posey. Reprinted from Proceedings 13th Congress of the International Association for Hydraulic Research, Kyoto, 1969.

40. "Fundamentals of Open Channel Hydraulics", Chesley J. Posey. RMHL, 1969.

41. "Hydraulic Jump Characteristics over Boundrock Erosion Protection", Gerard J. Gromko. October 1973.

42. "Protection of Offshore Structures against Underscour", Chesley J. Posey. Reprinted from Journal of the Hydraulics Division, ASCE, July 1971, with subsequent discussions.

43. "Erosion-proofing Drainage Channels", Chesley J. Posey. Reprinted from Journal of Soil and Water Conservation, Vol. 28, No. 2, March-April 1973.

44. "Erosion Control to Protect the Environment", Chesley J. Posey. Reprinted from Proceedings of the XVth Congress, International Association for Hydraulic Research, Istanbul, 1973.

45. "Erosion Control: Stability of Rock Sausages", Chesley J. Posey. University of Connecticut Institute of Water Resources Report No. 19, November 1973.

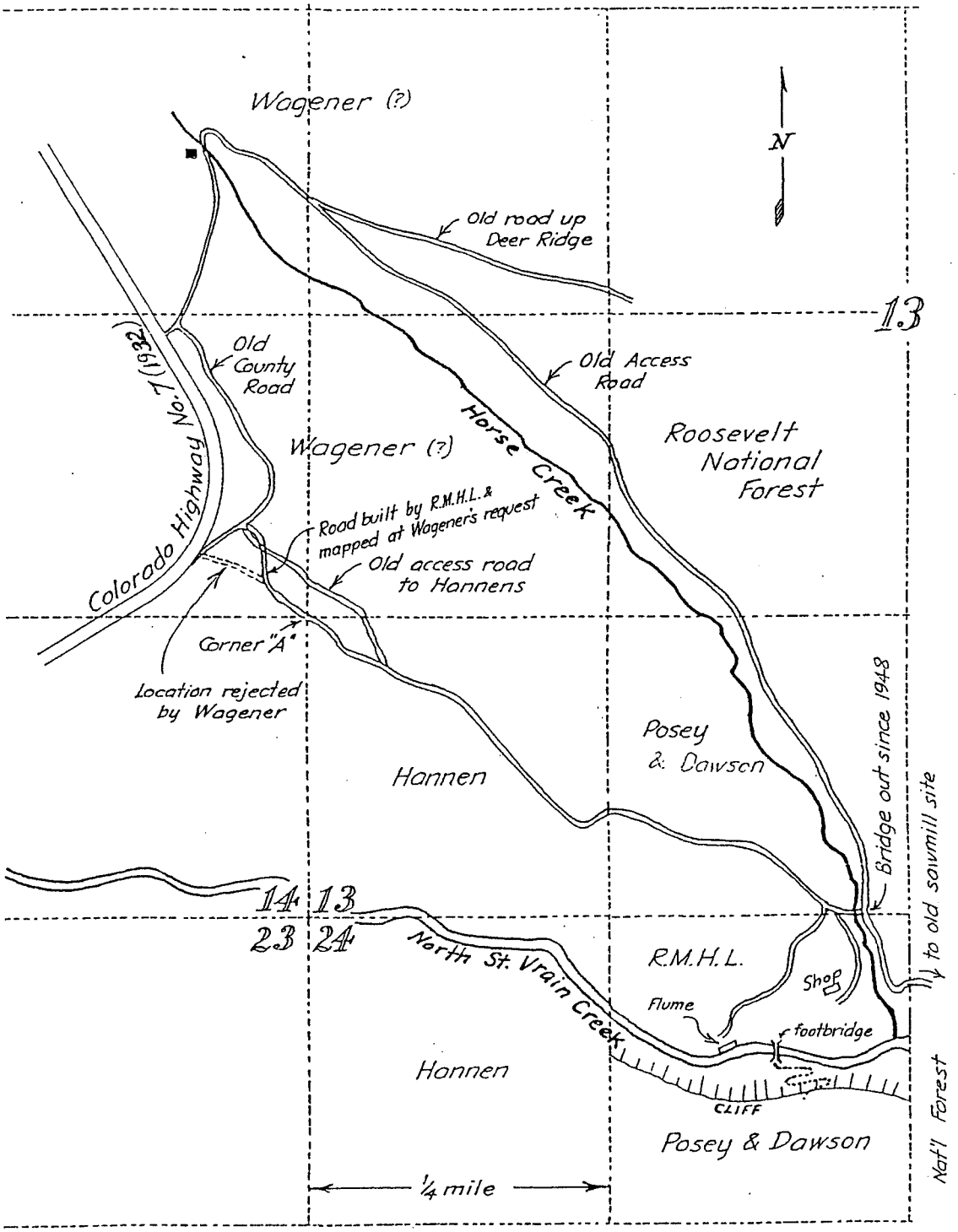
46. "Tests of Scour Protection for Bridge Piers", Chesley J. Posey. Reprinted from the Journal of the Hydraulics Division, Proc. ASCE, Vol. 100, No. HY12, December 1974, pp. 1773-1783.

47. "Economical Erosion Proofing of Supercritical Flow Sections", Dennis Morrow. RMHL, January 1976.

APPENDIX VI

MAP OF PROPERTY AND ADJOINING SITES

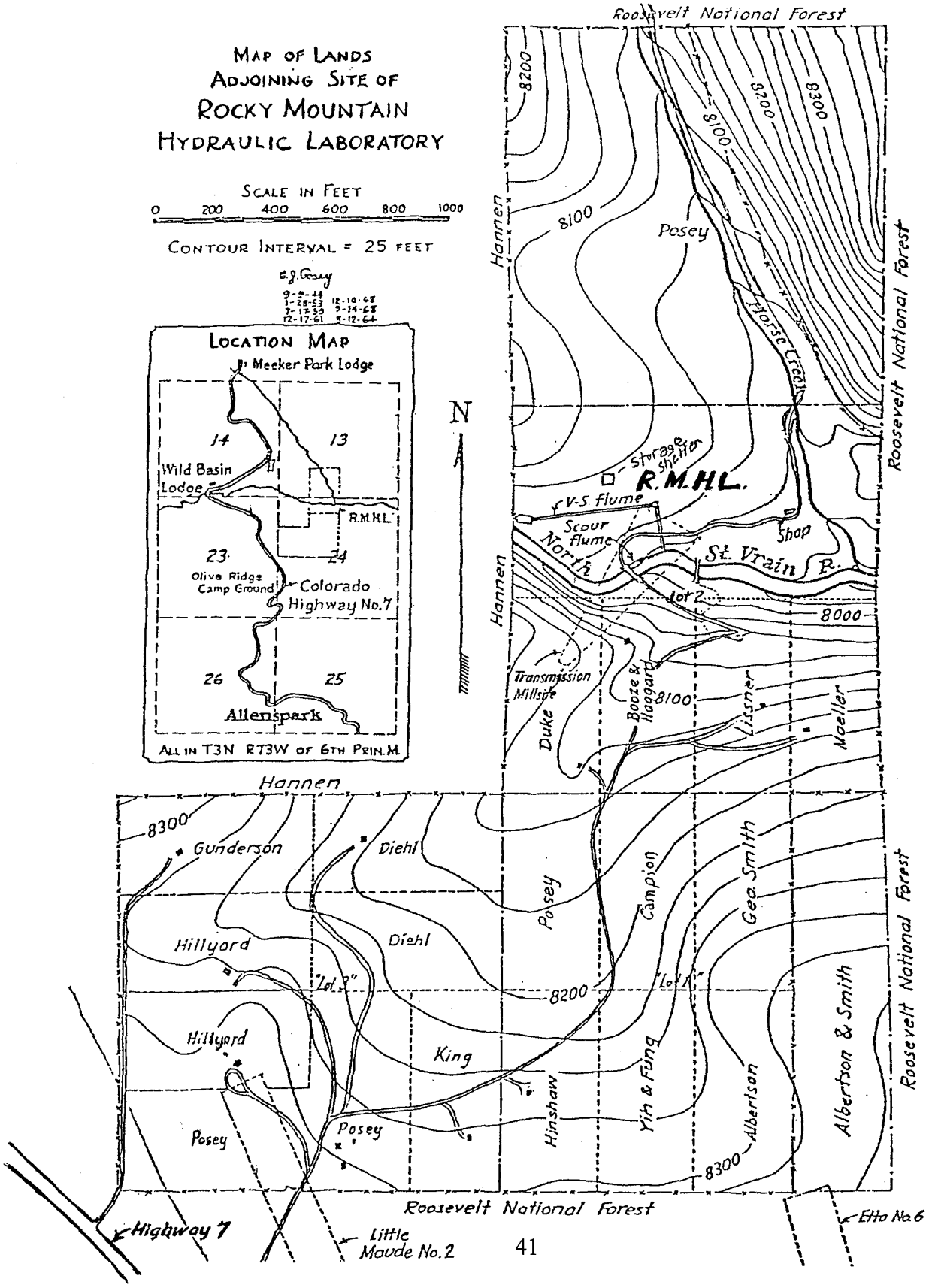
1964



APPENDIX VII

MAP OF ACCESS ROUTES

1988



APPENDIX VIII

SOURCES

Minutes of the Board of Trustees of the Rocky Mountain Hydraulic Laboratory and the Rocky Mountain Hydrologic Research Center, 1946-1995.*

Personal Interviews with William Moeller and Maurice Albertson, September 22, 1995.

Posey, Chesley. "The Rocky Mountain Hydraulic Laboratory". Iowa Transit, Iowa City: May 1946.*

Posey, Chesley. "The Rocky Mountain Hydraulic Laboratory". RMHL publication, Allenspark, CO: December 1960.*

Posey, Chesley. "Access to the RMHL". RMHL publication, Allenspark, CO: November 1988.*

Rocky Mountain Hydraulic Laboratory and Rocky Mountain Hydrologic Research Center reports and official papers.*

*Currently located at the Colorado Water Resources Research Institute, Colorado State University, Fort Collins, Colorado.