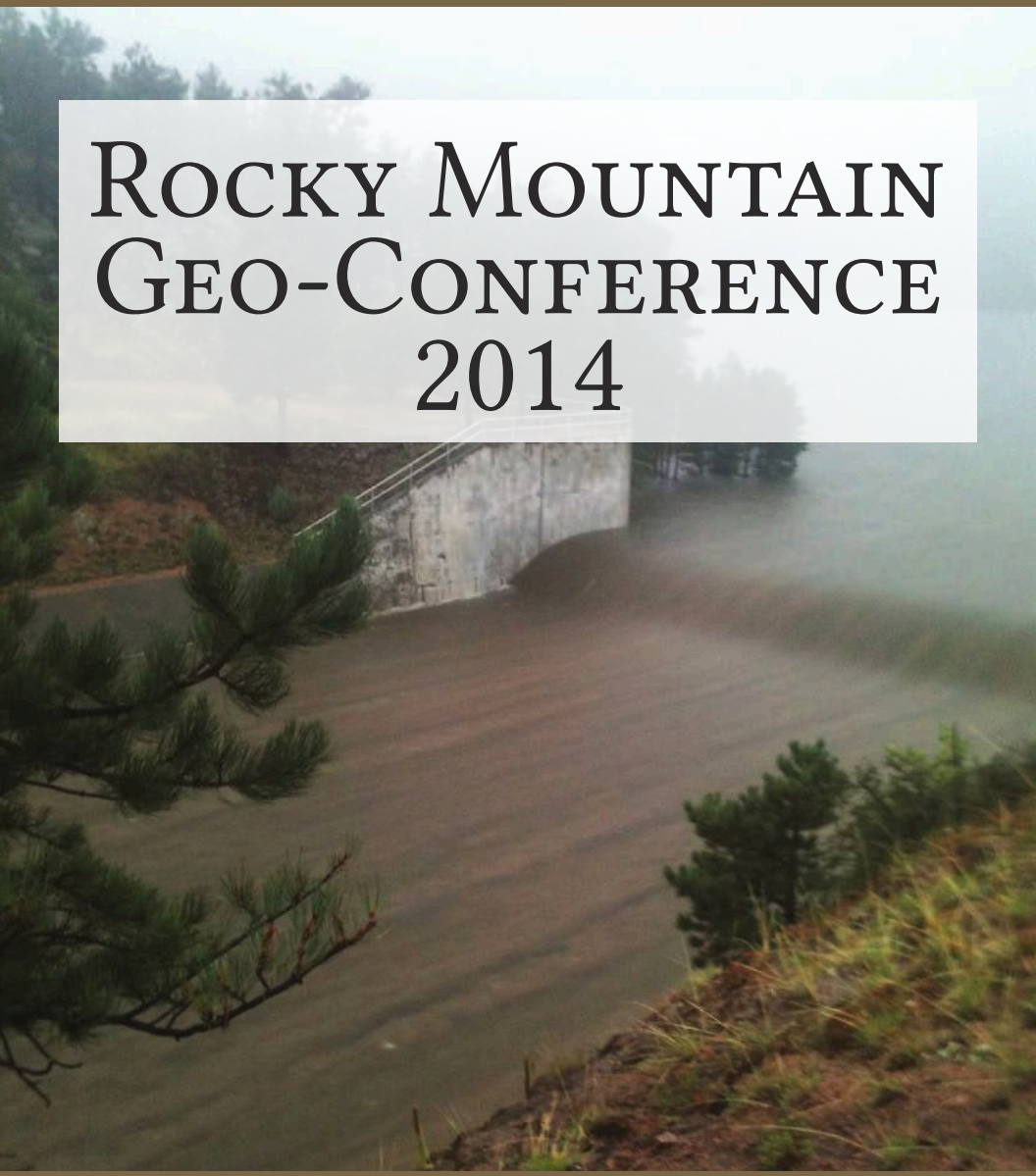
GEOTECHNICAL PRACTICE PUBLICATION NO. 9

Rocky Mountain Geo-Conference 2014



Edited by
Jere A. Strickland, P.E.
Richard L. Wiltshire, P.E.
Christoph M. Goss, Ph.D., P.E.

ASCE

G-I GEO-INSTITUTE ASCE

GEOTECHNICAL PRACTICE PUBLICATION NO. 9

ROCKY MOUNTAIN GEO-CONFERENCE 2014

PROCEEDINGS OF THE 2014 ROCKY MOUNTAIN GEO-CONFERENCE

November 7, 2014
Lakewood, Colorado

SPONSORED BY
The Geo-Institute of the American Society of Civil Engineers

Geo-Institute Chapter of the Colorado Section of the American Society of Civil Engineers

Rocky Mountain Section of the Association of Environmental and Engineering Geologists

Colorado Association of Geotechnical Engineers

EDITED BY
Jere A. Strickland, P.E.
Richard L. Wiltshire, P.E.
Christoph M. Goss, Ph.D., P.E.

Published by the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

2014 Rocky Mountain Geo-Conference (2014 : Lakewood, Colo.)
Rocky Mountain Geo-Conference 2014 : proceedings of the 2014 Rocky Mountain Geo-Conference, November 7, 2014, Lakewood, Colorado / sponsored by the Geo-Institute of the American Society of Civil Engineers [and 3 others] ; edited by Jere A. Strickland, P.E., Richard L. Wiltshire, P.E., Christoph M. Goss, Ph.D., P.E.
pages cm. -- (Geotechnical practice publication ; no. 9)
ISBN 978-0-7844-1380-7 (paper : alk. paper) 1. Engineering geology--Colorado--Congresses. I. Strickland, Jere, editor. II. Wiltshire, Richard L., editor. III. Goss, Christoph M., editor. IV. American Society of Civil Engineers. Geo-Institute, sponsoring body. V. Title.
TA705.3.C6B534 2014
624.1'5109788--dc23

2014033267

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/bookstore | ascelibrary.org

Errata: Errata, if any, can be found at http://dx.doi.org/10.1061/ 9780784413807.

ISBN 978-0-7844-1380-7 (paper)
Manufactured in the United States of America.

Front and Back Cover Photo Credit: Bill McCormick

Preface

As geo-professionals, we are called to provide solutions for the many challenges that our earth presents in the areas we choose to work, play and live. From nature's geological features to our world's aging infrastructure, we are presented with the challenge of developing in areas and in ways that many thought were unbuildable or un-attainable. Yet, through the use of new technologies, modeling methods and visual mapping, geo-professionals have answered these many challenges by providing viable solutions. This book provides examples of how some in our profession have overcome these types of challenges in mining applications, tunneling, geological anomalies, alternative energy resources and infrastructure. This will highlight, again, how the geo-professional community provides solutions to the most challenging applications.

Since 1984, the Geotechnical Institute Chapter of Colorado (formally known as the ASCE Colorado Section's Geotechnical Group) in collaboration with the Rocky Mountain Section of the Association of Environmental and Engineering Geologists and the Colorado Association of Geotechnical Engineers, has organized a biennial series of geotechnical seminars on a wide variety of themes that have been attended by as many as 270 civil/geotechnical engineers, geologists, and other geo-professionals. The geotechnical seminars have been held at area universities or hotels and have offered the opportunity for sharing ideas and experiences among Colorado's diverse geo-disciplines. Since 2004, ASCE's Geo-Institute has published the papers of these seminars in Geotechnical Practice Publications, allowing the experiences to be shared with a worldwide audience.

The Geo-Influence Steering Committee convened in August 2013 and held monthly meetings to plan for the 2014 Rocky Mountain Geo-Conference. The Steering Committee members included Christoph Goss (Conference Chair), Sam Adettiwar, Dustin Bennetts, Mark Brooks, Laura Campbell, Robin Dornfest, Darin Duran, Julia Frazier, Evan Friedman, Joseph Kerrigan, Joels Malama, Bill McCarron, Minal Parekh, Becky Roland, Jere Strickland, Lindsay Tita, Mark Vessely, Chris Wienecke, Richard Wiltshire, and John Worthen.

Jere Strickland, Richard Wiltshire, and Christoph Goss

Acknowledgments

The GeoChallenges Steering Committee wishes to take this opportunity to thank all of the authors and reviewers of our papers, which are herein presented as Geotechnical Practice Publication No. 9. The authors have spent many hours in preparing and finalizing their papers, which will be presented at the 2014 Rocky Mountain Geo-Conference on November 7, 2014. These papers have been reviewed by a volunteer group of Denver area geo-professionals who put in their valuable time and helped make these papers even better. The Geo-Institute's Committee on Technical Publications completed its review of our papers in a very timely manner and their adherence to our aggressive publication schedule is greatly appreciated. We would also like to acknowledge the assistance of Donna Dickert of ASCE's Publications Division for putting this publication together.

Contents

Author List

Dam Performance along Left Hand Creek during the Front Range Flood of 2013

Richard J. Tocher[1], P.E, M. ASCE and L. Clint Brown[2], P.E.

[1]Principal, Engineering Analytics, Inc. 1860 Blake Street, Ste 200, Denver, CO 80202 rtocher@enganalytics.com
[2]Project Manager, Engineering Analytics, Inc., 1600 Specht Point Road, Ste 209, Fort Collins, CO 80525 cbrown@enganalytics.com

ABSTRACT: Severe flooding on the Front Range of Colorado in September 2013 tested many dams including several dams on and adjacent to the Left Hand Creek drainage north of Boulder, Colorado. A tropical-like storm drove moisture up against the foothills dropping 200 mm (8 in) to more than 350 mm (14 in) of precipitation in a 24-hour period based on a number of weather stations within the watershed. The precipitation resulted in flash flooding in Left Hand Creek. A dam west of the main precipitation event experienced no damage. A diversion dam near the mouth of Left Hand Canyon was completely destroyed by the storm event due to scour. An off-channel valley reservoir dam experienced damage to both the service and emergency spillways. The experiences along Left Hand Creek demonstrate the need for geotechnical and structural design of dams for extreme events especially in mountain environments where uncertain flood events can occur due to unusual weather patterns.

INTRODUCTION

Left Hand Creek is 55 km (34 miles) long from its headwaters on Niwot Ridge at an elevation of over 3660 m (12,000 ft) to its confluence with St. Vrain Creek as shown on Fig. 1. The creek descends from the mountains in a steep canyon, known as Left Hand Canyon. It emerges from the foothills north of Boulder, Colorado and crosses the Colorado Piedmont, passing north of Niwot and joining St. Vrain Creek on the south side of Longmont. The basin covers 186 km^2 (72 sq miles) and discharges into the St. Vrain Creek in Longmont at an elevation of 1500 m (4924 ft).

GEOLOGIC SETTING

Pre-Cambrian metamorphic and granitic rocks dominate the geology of the mountainous portions of the watershed, including intrusive stocks and dikes. Glacial deposits occur near the upper watershed alongside and west of Highway 72. These are

mostly glacial moraine material rather than glacial outwash, and can reach up to 15 m (50 ft) thick in some locations. The crystalline rocks within the watershed contain

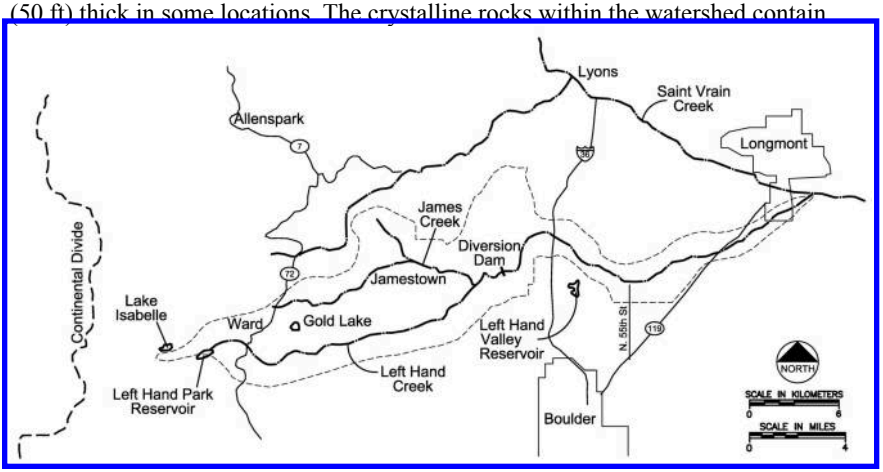


FIG. 1. Left Hand Creek Watershed

several minerals in extractable quantities, including gold, fluorite, lead, silver, uranium, tungsten, and copper. These minerals were deposited with intrusions of molten igneous rocks during periods of mountain uplift. Soils in the watershed are fairly thin.

The Left Hand Creek watershed covers portions of two distinct physiographic regions: the Southern Rocky Mountain province and the Colorado Piedmont section of the Great Plains province. Foothills separate these distinct topographical features. Glaciation, stream erosion and deposition, wind erosion, and atmospheric weathering formed and continue to alter the watershed topography. The watershed features gentle slopes concentrated near the upper reaches of the watershed and steep canyon reaches near the watershed mouth. Although some glacial deposits are present near the upper watershed, the canyons in the middle and lower portions of the watershed have a V-shaped morphology, formed by water flow rather than glacial ice.

SEPTEMBER 2013 FLOOD EVENT

The Front Range of Colorado experienced an unusually moist and persistent weather pattern from September 9 through 15, 2013. The storm dropped all time record precipitation in the area north of Boulder, Colorado with some areas receiving over 400 mm (16 in) of rain. The event was caused by a near stationary low pressure system over eastern Nevada that pulled tropical moisture from the Pacific Ocean and the Gulf of Mexico. An upslope condition developed along the foothills creating the large rainfall. Most of the rainfall occurred over 36 hours between September 11 and 13. The event was similar to a storm in 1938 that also occurred in September. The peak rainfall intensities were lower than previous storms but the intensity of the storm was about 5 mm (0.2 in) per hour from September 11 through 13 with a peak

intensity of 28 mm (1.1 in) per hour. There were sufficient rain gages in the watershed (NOAA, 2013) to construct total event precipitation contours as shown in Fig. 2. About 40 percent of the basin received over 355 mm (14 in) of precipitation from the event.

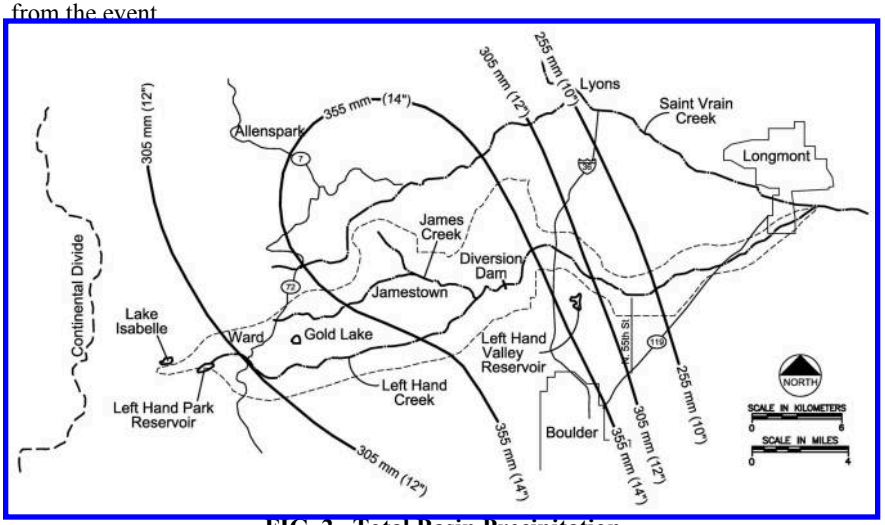


FIG. 2. Total Basin Precipitation

Once the floodwaters receded, Left Hand Ditch Company engineers found that Left Hand Creek had to be re-channeled to its original course over 1.6 km (1 mile) in an area of critical diversion structures and head gates. Some sections of the company's systems were completely destroyed. When applying for emergency loans from the Colorado Water Conservation Board, the company estimated the cost to repair the damage would be $3.2 million. Without critical repairs to the company's infrastructure, a significant portion of irrigated farm land in Boulder County and the company's five reservoirs would have been unusable for the following irrigation season. One of those reservoirs provides water for residential use in the Left Hand Water District.

The U.S. Geological Survey (1988) study of peak flows in the creeks surrounding Left Hand Creek generated a series of empirical correlations for flood levels based on elevation and drainage basin area below an elevation of 2440 m (8000 ft). These correlations were used to calculate exceedance probabilities for Left Hand Creek at the Allen's Lake diversion dam, North 55th Street, and the confluence with the St. Vrain Creek as shown in Fig. 3. The results show a 100-year recurrence flow of 120 m^3/s (4300 cfs) at the diversion structure. This estimated flow was not able to be verified by field measurements during the flood event.

Damage along Left Hand Creek and its tributary James Creek was massive. Photographs 1 and 2 show the degree and damage sustained.