ground water

Historical Note/ David Deming, History Editor

Daniel W. Mead, Pioneer Educator, Ethicist, and Consultant

by Mary P. Anderson[1]

Introduction

An early textbook in hydrology (Mead 1919) contains a remarkable chapter on ground water as well as two chapters on geology. The author, Daniel W. Mead, a professor of hydraulic and sanitary engineering at the University of Wisconsin (now the University of Wisconsin-Madison), based the text on lecture notes (published earlier, Mead [1904]) for his course in general hydrology. In fact, Professor Mead (Figure 1) had been teaching a course in general hydrology since 1904, the first of its kind in the United States according to Turneaure et al. (1948), including, we must assume, material on ground water hydrology. In the preface to the 1919 text, Mead commented on the status of hydrology as an academic discipline:

> While hydrology is by no means a new subject it has received far less study and attention than its importance warrants. Some of the phenomena have been discussed in treatises on water supply and sewerage, but the subject has been introduced as a separate technical study in engineering schools only within the last fifteen years. (Mead 1919, v)

Mead's earlier work (Mead 1904), which included an eight-page chapter on ground water, was "not wholly satisfactory" (Mead 1919, vi) and was soon out of print. In the introduction to the 1904 work, Mead commented on the lack of a text in hydrology:

> "The volume of literature covering many of the various branches of this subject is very great. Unfortunately, however, there is no single treatise which discusses the entire subject, and which can be utilized as a textbook or reference book, to which the student may turn when investigating the various branches of this science. The lack of such a work is the reason for the preparation of these notes, which are intended to be used in connection with various publications to which references are given."

It appears that Mead's 1904 publication was the first textbook in hydrology, and his 1919 text could be regarded as an extensively rewritten and expanded second edition of the 1904 work. In the years between the publication of the notes in 1904 and the appearance of the 1919 textbook, another textbook on hydrology was published (Meyer 1917), which also contains a very nice chapter on ground water but without accompanying chapters on geology. While later works by Meinzer (1923a, 1923b) and the excellent text by Tolman (1937), which is often cited as the first textbook in ground water hydrology, contain much more extensive treatments of ground water, Mead's textbook is remarkable in that it demonstrates an early appreciation of hydrogeology by an engineer.

Engineering Consultant and Professor

Daniel Webster Mead was born in Fulton, New York, on March 6, 1862, but grew up in Rockford, Illinois. After receiving a BS in civil engineering from Cornell University in 1884, he worked for the USGS in Madison, Wisconsin, under the famous glacial geologist, T.C. Chamberlin, noted for seminal work in ground water (Anderson 2005). Later, Mead worked as an engineer for the city of Rockford, the Rockford Water Power Company, and the Rockford Construction Company, gaining valuable experience that would feed his future as a professor and consulting engineer. For example, in 1887, he designed and was contractor for a ground water supply system for the city of Rockford. In 1900, he formed his own consulting firm in Chicago.

One of the students Mead supervised while working in Rockford was Frederick Eugene Turneaure, who became dean of the College of Engineering at the University of Wisconsin in 1903, serving in that capacity until 1937. Turneaure thought that Mead, with his wealth of practical experience and interest in education, would be perfect to head a new department of hydraulic and sanitary engineering. In 1904, Mead accepted an invitation to join the faculty with the stipulation that he be allowed time to continue his consulting work. In 1906, he opened an office of his consulting firm in Madison, which grew

[1]Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, WI 53706; andy@geology.wisc.edu

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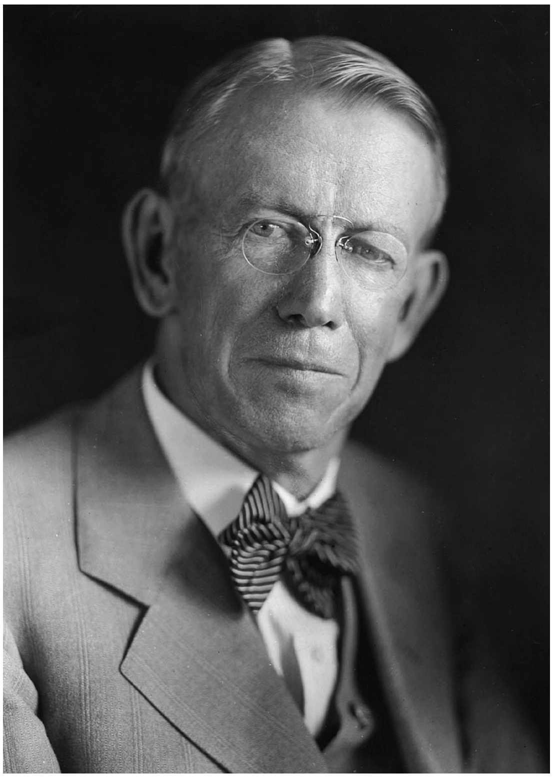

Figure 1. Professor D.W. Mead, 1932 (photo courtesy Mead & Hunt).

into the consulting firm of Mead & Hunt, currently with five offices in Wisconsin as well as offices in California, Oregon, Michigan, Minnesota, and Washington, D.C. (http://www.meadhunt.com). Mead's son, Harold, was president of Mead & Hunt in the 1950s, and with his consulting partner, Henry J. Hunt, Harold undertook a revision of the 1919 textbook (Mead 1950), including a new chapter on drought. Except for the addition of a section on ground water recession, the chapter on ground water remained unchanged.

Professor Mead taught at the University of Wisconsin until 1932, when he retired as emeritus professor. He died on October 13, 1948, and is buried in Madison.

Mead's Understanding of Ground Water Hydrology

Mead's own work was mainly focused on hydroelectric plants, dams, and floods. During his tenure with the university, he was granted three extended leaves to pursue consulting work (University of Wisconsin-Madison 1948), all related to surface water hydrology. Specifically, he helped with flood control on the Huai River, China (1914), worked with the Miami Flood Control Conservancy District in Ohio (1915-1920), and was appointed by President Coolidge to help design the Hoover Dam (1928-1929). Nevertheless, he clearly was familiar with the principles of geology and ground water hydrology as understood at the time, citing works by Darcy, Meinzer, Darton, Chamberlin, and Slichter as well as King, Fuller, and Leverett in his textbook.

Mead's 42-page chapter on ground water hydrology (Mead 1919) contains descriptive material on the origin and occurrence of ground water, as well as discussion of springs, artesian conditions, and temperature and quality of ground water, all accompanied by beautifully drawn figures. A figure showing ground water flow in and out of ponds (Figure 2) nicely illustrates what we now refer to as a discharge lake (for lakes receiving ground water inflow) and a recharge lake (for lakes feeding the ground water system). This level of understanding is noteworthy in an era when the standard conceptual model portrayed lakes as isolated or sealed from the ground water system by impermeable lakebed sediments. Other figures show geological cross sections of artesian conditions in the Dakota Aquifer, the Atlantic coastal plain, the San Joaquin Valley, California, and beneath Fort Worth, Texas.

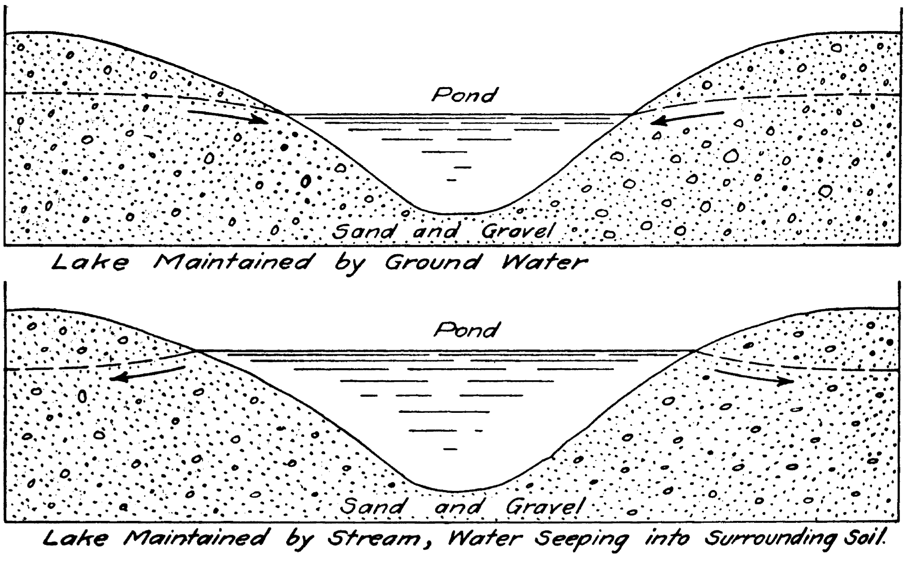

Figure 2. Schematic illustrations of ground water interaction with surface water showing ground water discharge conditions (upper figure) and ground water recharge conditions (lower figure) (Mead 1919, 394).

Mead cites work by his mentor, Chamberlin, indicating he had absorbed Chamberlin's (1885) ideas about artesian conditions. Also, following Chamberlin's ideas, he states in an introductory chapter, "All geological deposits are more or less pervious and water under the action of gravity forces its way wherever rock structure will admit of its presence." (Interestingly, Mead consistently misspelled Chamberlin's name as Chamberlain. Spelling was not one of his strengths; he maintained that poor spelling is indicative of a logical mind, [Turneaure et al. 1948].)

Most importantly, however, there is a section on Darcy's law including discussion of Slichter's related work on ground water velocity. Meinzer's later treatises on ground water (Meinzer 1923a, 1923b) are largely qualitative discussions on ground water occurrence and surprisingly omit mention of the quantitative work of Darcy and Slichter. Slichter was a professor at the University of Wisconsin from 1889 to 1934 (Anderson 2005) and thus a contemporary of Mead. In fact, Slichter and Mead belonged to some common social clubs in Madison. Slichter also worked part-time for the USGS. Hence, presumably he was known to Meinzer as well.

Mead cites Slichter's work at length (e.g., Slichter 1899), relating Slichter's experimental formulas to Darcy's law and identifying hydraulic conductivity in Darcy's law as the "transmission coefficient." He also cites Slichter's work to show that ground water velocity is temperature dependent and thus the transmission coefficient is dependent on the viscosity of water. He uses Slichter's measurements of ground water velocity in a buried river channel to illustrate that velocity "varies greatly in accordance with the materials, the porosities and the contour of the underground channel." As a good engineer, he also voices healthy skepticism over calculations based on Darcy's law:

> It should be understood that any calculations of the velocity of flow of ground water can be regarded only as a rough approximation which will undoubtedly vary widely from the truth as developed by actual determination of flow by experiment or from the measurement of flow into wells, infiltration galleries, etc., and in consequence large factors of safety must be allowed in making estimates which are to serve as bases for investments. (Mead 1919, 421)

Mead's treatment is also interesting because it shows that hydrologists were still struggling with the concepts of hydraulic conductivity and the definition of velocity. Hydraulic conductivity was regarded as a rather mysterious empirical constant dependent on porosity. Nor did Mead appreciate the distinction between the Darcy flux ($q = KI$, where K is hydraulic conductivity and I is hydraulic gradient) and average linear velocity ($v = q/n$ where n is effective porosity).

Mead also includes a discussion of the effects of pumping on the water table. Evidently, he was not aware of the work of Theim (1887) in Germany, but presented an equation derived by Turneaure and Russell (1910) for calculating the extent of the cone of depression caused by pumping in an unconfined aquifer (Mead 1919, 425, equation 5). This equation, essentially a version of the Theim equation for unconfined aquifers, is easily derived from Darcy's law (e.g., see Fetter 1994, 219, equation 7-44). Mead also discusses well interference and overlapping cones of depression, presenting a version of the now familiar figure showing the effects of pumping from closely spaced wells.

Mead recognized the importance of geology to hydrology. The chapter "Geological Agencies and their Work" includes sections on the origin and permanency of lakes, and another chapter contains a primer on historical geology including effects of glaciation.

Ethics and Professional Standards

In the latter portion of his career, Mead focused on ethics in engineering, an interest perhaps fostered by intimations that surfaced when he was working on power development of the St. Lawrence River (Mead 1935). There were suggestions he was subject to bias or outside influence, to which he famously replied that his services were always for sale but never his opinions (Turneaure et al. 1948). He was active in the American Society of Civil Engineers (ASCE), serving as its president in 1936, and in 1939 he established the Daniel W. Mead prize for engineering ethics for students and young engineers in the ASCE (http://www.asce.org/pressroom/honors/honors_details.cfm?hdlid=43). After 3 years of persuading the various committees in ASCE of the need, he was finally authorized to prepare a manual on the "Standards of Professional Relations and Conduct" for the ASCE (Mead 1941a), which was first published in the ASCE Transactions with 38 pages of discussion (Mead 1941b). The society had earlier (in 1914) adopted a code of ethics and currently maintains both the code and a revised version of the standards (http://www.asce.org/professional/ethics/). The manual was driven by a need "to make available to the younger men of the profession" conclusions and opinions he had formed during his 56-year career as a consulting engineer.

The standards are organized into 10 sections including advice to the engineering student and young engineer, principles of courtesy and personal conduct, and guidelines for personal, business, and public relations and for relations with clients and employers, employees, and contractors, as well as a section on the ethics of contracting. But more interesting is the first portion of the manual, which includes observations about personal characteristics necessary for success. It is from these that some insights into Mead's personality can be gleaned. For example,

> Time is one of the most important possessions of every one and its proper expenditure is very important. If time is wasted in the minor pleasures of life instead of being used in the development and improvement of talents and opportunities then only minor professional advancement can be expected. (Mead 1941a, 4)

He goes on to say that there are 4 h a day of spare time and at least 2 h of these should be used for professional development outside of the regular 8 h of work.

Mead was convinced that while some measure of intelligence is helpful to achieve success, the will to succeed is essential.

> If the individual neglects his own personal power of self-control, and will to achieve, he will float with the tide of affairs and take only that share of life which comes to him naturally . . . . Genius is but the exercise of infinite pains to accomplish a desired end. (Mead 1941a, 5–6)

> Success (however it may be defined) depends on two essential factors—opportunity and the man . . . . Opportunity is almost always present and almost always at hand if the individual has the intelligence to recognize it and the energy to utilize it. The discouraging feature to be young is that, commonly, opportunity presents itself in the disguise of hard work and, therefore, is not always recognized nor received with enthusiasm. (Mead 1941a, 9)

He quotes a poem titled *Opportunity* by one Walter Malone, which includes the lines:

> For every day I stand outside your door
>
> And bid you wake, and rise to fight and win.

The "I" in the first line refers to opportunity. Mead evidently had a predilection for this sort of rhyme; late in his life, he was able to recite from memory quite a long poem (*Darius Green and His Flying Machine* by John T. Trowbridge, http://www.skygod.com/quotes/darius.html) learned in childhood (Turneaure et al. 1948).

Hydrology as an Interdisciplinary Science

Mead appreciated that hydrology is an interdisciplinary science:

> The phenomena and laws of all sciences are so interwoven that it has been said if a student has a complete knowledge of any one he will have a complete knowledge of all. In a practical way, this idea is true to the extent that no science can be satisfactorily acquired without trespassing to a degree on many other sciences. So in the study of Hydrology we must, to an extent at least, seek information from Meteorology, Geography, Geology, Physiography, Agriculture, Forestry, and from the field of Hydraulic Engineering of which Hydrology is the basic study. (Mead 1919, 1)

Likely, he drew upon these related disciplines in his consulting work. However, there is no evidence that he engaged in interdisciplinary research at the university. The period roughly from 1875 to 1940 was a golden era of hydrology at the University of Wisconsin, with geologist T.C. Chamberlin, mathematician C.S. Slichter, and the limnologists E.O. Birge and C.C. Juday (Anderson 2005) as well as the engineer D.W. Mead, in residence during part of this time. Yet, each seemingly worked in his own sphere; except for work by Birge and Juday, there are no jointly authored publications among these men. It appears that interdisciplinary collaboration in academia was as difficult to pull off then as it is today.

Acknowledgments

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