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Groundwater, A Century of Word Evolution

A. F. Diefendorf

Environmental Sciences Division
Publication No. 4446

MANAGED BY
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FOR THE UNITED STATES
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Environmental Sciences Division

GROUNDWATER, A CENTURY OF WORD EVOLUTION

A. F. Diefendorf

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Prepared for
Lockheed Martin Energy Systems, Inc.
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1. INTRODUCTION

Words, especially those that apply directly to more than one discipline, often become the object of intense debate among professionals in those disciplines. This is particularly true with those people who have to deal with technical jargon on a day-to-day basis and who are concerned that scientific facts get communicated in as clear and concise a manner as possible. Communications regarding environmental restoration projects for the U. S. Department of Energy are no exception. Lockheed Martin Energy Systems, Inc., its subcontractors and other prime contractors often disagree about the spelling and use of compound words. This frequently results in inconsistent spelling between project reports and incorrect spelling of referenced document titles. The following discussion is an attempt to provide an objective, in-depth examination of the evolution of one particular word and recommendations for its proper and consistent use. This discussion is the result of an extensive literature search conducted within the library system at Oak Ridge National Laboratory as well as the personal geologic libraries of the author and colleagues. The author has attempted to cite only those works produced by recognized names in the related disciplines or those works that constitute common references or glossaries.

Often a debate over the use, form or meaning of a word arises between different but related professions, each claiming ownership of the word. As an example, geology's subdiscipline of hydrogeology focuses on the geologic system as it relates to the properties and behavior of *ground water*. The engineering hydrology discipline of geohydrology, on the other hand, focuses on the hydraulics of *groundwater* as it relates to earth materials. The two disciplines have a different perspective, yet they agree on the same definition for their medium of interest—which one discipline calls *groundwater* and the other calls *ground water*. Which form is correct?

Both the compound word, *groundwater*, and its simpler root form, *ground water*, are accepted noun forms with the same meaning. The importance is that the noun, like many others, be recognized as undergoing transition into a compound word. Compounding of words is an evolutionary process generally initiated by writing habits and a "need" to simplify the writing process. Strunk and White (1979) note that "the steady evolution of the language seems to favor union." The frequent use of an old word to support the latest area of technological interest, such as the environment, often forces this union. Fortunately, compounding words is not abhorrent to most technical readers because it often leads to clarity of communication.

As will be discussed herein, the evolution of the word *groundwater* to its popular acceptance in the one-word form has taken place over a period of about one hundred years. As with any new word, its initial use, regardless of form, was accepted cautiously. Because the word construction can be in three different forms—*ground water*, *ground-water* and *groundwater*—the potential for different preferences for the word form and inconsistencies in word-form use is great. The following discussions summarize the etymology of the word. Section 2 discusses the history of the noun, Section 3 touches on the linguistics of the word, Section 4 discusses the proper use of modifiers, and Section 5 presents conclusions and recommendations regarding the word's use.

2. HISTORY OF THE NOUN

2.1 THE EARLY HISTORY—2000 YEARS OF GESTATION

Written discussions about the occurrence and movement of water beneath the surface of the earth go back at least as far as Aristotle's *Meteorologica*, but naming of these waters is relatively recent. Agricola (1546), a Saxon physician and chemist, referred to the *canales* in the earth through which the water flowed like blood in an animal's veins. Athanasius Kircher (1678), a Thuringian Jesuit, discussed *water-chambers* and the juices of minerals. The French and Germans were actively engaged in hydrologic theory in the late 1800s—including such scientists as Darcy (1856) and Dupuit (1863). During Henri Darcy's time consistent hydrologic terminology began to be used, but at that time in France the waters were referred to as *les eaux souterraines*. American authors such as Dana (1875) made no reference to *groundwater*. Even by 1886, Winchell's works either do not mention the subject or refer to *underground* or *subterranean waters*.

2.2 1875–1900—BIRTH OF THE NOUN

The tenth edition of *Merriam-Webster's Collegiate Dictionary* (1993) gives 1889 as the birth of the word *groundwater*. *The Oxford English Dictionary* (1933) gives a date of 1890 and references the journal *Nature*. These dates of origin correlate well with an English translation of a work by Pošepný (1893) that uses the words *ground water* and *ground-water*, both in noun form. Pošepný's original text used typical Germanic compound nouns such as *Grundwasser* for *groundwater* and *Grundwasserspiegel* for *groundwater level*. The English words for *groundwater* may be directly derived from the Germanic or as a shortened form of the English *underground water*. LeConte used the hyphenated word *ground-water* in his *Compend of Geology* (1898). So, it appears that the birth of the noun in the English language, regardless of source, was in both the two-word and hyphenated-word form and may also have been in the one-word form.

2.3 1900–1925—LIMITED USE AND MIXED NOUN FORMS

Publications in the United States that used the word were rare until the beginning of the twentieth century. A review of Mead's (1919) work indicates a persistence in the United States, even during the early 1900s, to refer to those waters as *underground waters*, although Mead himself used the two-word form *ground water*. Most early U. S. Geological Survey (USGS) Professional Papers used *underground waters*, as did Ambrose as late as 1921. By 1910, however, some articles were using the noun *ground water*; although, in that same year, G. E. P. Smith published a paper using *groundwater* in the title. Emmons' (1917) USGS Bulletin on enrichment of ore bodies used the two-word form. The two-word form appears to be the most prevalent in use after the first World War, particularly by such noted hydrologists as Meinzer (1923).

2.4 1925–1950—THE TWO-WORD FORM PREDOMINATES

The Oxford English Dictionary (1933), a work of thirteen volumes, had no direct listing for *ground water* or *groundwater*. The word *ground-water* was noted under special constructions of the word *ground*. The etymology of the two-word form *ground water* was discussed as “a word or form not found, but of which the existence is inferred.” Etymologically, it appears that the noun was used earlier in American English than in British English, even though it was not listed in the *Dictionary of American English* (1940). Where the word was used in American English publications during this period, the two-word form *ground water* predominated.

Textbooks on hydrogeology that predate the 1950s are rare; Tolman’s (1937) *Ground Water* being an exception. Treatment of the subject is usually limited to small sections of general geology texts. Troxell (1936) used the hyphenated-word form. Most related information during this period is found in geohydrology textbooks such as Meinzer’s (1942) *Hydrology*. Meinzer generally continued to use the two-word form. Legget (1939) used *groundwater* in the first edition of his text *Geology and Engineering*. Some well-known authors of the period, who appear to have been inconsistent in their usage of the noun, included Jacob (1943, 1945) and Theis (1935, 1937). The well-known geologist M. K. Hubbert (1940) used the two-word form, as did Landes and Wilson (1943). The second edition of *Webster’s New International Dictionary* (1947) appears to be the first listing for the word by Webster’s. In this edition the two-word form is presented. Noted soils engineers, Terzaghi and Peck (1948), avoided the use of the noun altogether in their well-known text. Trefethen (1949) in his *Geology for Engineers* used the two-word form and also frequently used *underground water*.

2.5 1950–1960—COMPOUNDING OF THE NOUN INITIATED

Compounding of word forms generally goes through an intermediate stage wherein the compounded form is usually hyphenated. However, the noun *ground-water* is rarely found in earlier literature, with the exceptions of LeConte (1898), Troxell (1936) and Peele (1941). Usually the hyphenated form has been reserved for the modifier or adjective form of the noun where the two-word form of the noun is used. Two listings for the noun *ground-water* were found in 1950s references—one in the Britannica World Language edition of *Funk & Wagnalls New Practical Standard Dictionary* (1955) and the other in *Dictionary of Geological Terms* (Rice 1955). Rice’s work used the hyphenated form for both the noun and the adjective.

No British references with the hyphenated form were found for this period. In fact, *The Shorter Oxford English Dictionary* (1955) had no listing for the noun at all, probably representing general British distaste for additions to their language. However, the apparent establishment of the hyphenated form had taken place and was carried on in Britain in the 1960s, as exhibited in *A Dictionary of Geology* by John Challinor (1967) and Holmes’ (1965) tome on physical geology.

Rather than use the hyphenated form, most authors of the 1950s continued to use the two-word form. These authors included Krynine and Judd (1957), Todd (1959) and Walton (1955). The American Geological Institute's first version of its *Glossary of Geology* (1960) recognized only the two-word noun. It was, however, during this period that the one-word form did become popular with such authors as Ferris and Sayre (1955).

2.6 1960–1970—COMPOUNDING TO GROUNDWATER ACCELERATES

The evolutionary process of actively compounding *ground water* into the one-word form appears to have accelerated in the early 1960s and was influenced by the activity of geohydrologists as opposed to hydrogeologists. The well-known hydrology text *Groundwater and Seepage* by Harr (1962) is a good example. The third edition of *Webster's New International Dictionary* (1961) also combined the words into the one-word form. Most engineering texts, journals and articles have used the compound form since the late 1960s. This includes Walton's (1970) text *Groundwater Resource Evaluation*. Many others in the forefront of groundwater work used the one-word form during this period, including Cooper (1966), Prickett et al. (1964), Freeze and Witherspoon (1966), and Bredehoeft and Papadopoulos (1965). Many organizations involved with the practical problems of groundwater quickly adopted the one-word form. The American Society of Agricultural Engineers gave the preferred word construction as *groundwater* in 1967 in its *Glossary of Soil and Water Terms*, as did Nelson and Nelson (1967) in their *Dictionary of Applied Geology*.

Vollmer's (1967) *Encyclopaedia of Hydraulics*, the Bureau of Mines' (U. S. Department of the Interior 1968) *Dictionary of Mining, Mineral and Related Terms*, and Elsevier's *Dictionary of Hydrogeology* (1969) continued to list the two-word noun with the hyphenated adjective. Noted authors such as DeWiest (1965), Davis and DeWiest (1966), and Legget (1962) preferred the two-word form of the noun. Legget is a rarity in that he split apart the one-word form used in his first edition (1939). Some British factions remained steadfast—no listings were found in *The Concise Oxford Dictionary* (1964). However, a two-word, unhyphenated form was finally identified in a British reference, the *Meteorological Glossary* (1963).

2.7 1970–1980—HYDROGEOLOGISTS AND GEOHYDROLOGISTS ENTRENCH

Open disagreement over the correct use of the word form began in the early 1970s. Few hydrogeologists worked in the private sector at that time; most were employed by the USGS or in academia. Some worked for civil engineering firms and they soon learned that engineers, particularly geohydrologists, had a lot invested in the word *groundwater*. An engineer once explained to this author that one reason for compounding the word was improved clarity. There was some concern that *ground water* might actually be interpreted by the layman as water that had been *ground up*. Later discussions herein somewhat support that concern based on the differences in oral stress between the two different word forms.

The USGS in its *Suggestions to Authors* (1978) presented *ground water* as its preferred form. This, in effect, somewhat polarized many geologists against engineers on the topic. Geologists in the past have been far more insular, academic and resistant to change than those in more publicly active professions. As a result, other professions and the public tend to follow the path set by engineers rather than geologists. This has probably been the single most important element in the rapid evolution and acceptance of the one-word form *groundwater*. As a result of the apparent influence of those outside the geologic community, as well as others within, the American Geological Institute's 1972 edition of the *Glossary of Geology* altered from its original version and, instead listed all three word forms. *Webster's New Collegiate Dictionary* (1973), on the other hand, began to list only the one-word form *groundwater*. All subsequent Webster's editions, from seventh to tenth, have used that form only. UNESCO's *International Glossary of Hydrology* (1974) used only the one-word form.

During this period Todd (1980) changed the title of his second edition to *Groundwater Hydrology*, following in the steps of Walton and others who had already made the conversion. Others, including Domenico (1972), Bredehoeft and Pinder (1973), Neuman (1973), Nuzman (1978) and Bear (1979) used the one-word form in their titles.

Bouwer (1978) used the two-word form in his text, *Ground-water Hydrology*. Listings of the two-word form found in the 1970s reference literature included Durrenberger's (1973) *Dictionary of Environmental Sciences*, *The American Heritage Dictionary of the English Language* (1976), *Black's Law Dictionary* (1979), the reference text *Ground Water and Wells* (1972), and the U.S. Department of the Interior's *Ground Water Manual* (1977). None of those listings had a secondary reference to the one-word form.

2.8 1980-1989—THE ONE-WORD FORM PREDOMINATES

Some hydrogeologists, geologists and even a few engineers elected to use the two-word convention *ground water* throughout the 1980s. This continued to undoubtedly be influenced by the USGS and the existence of journals by the National Water Well Association (recently changed to the National *Ground Water* Association) titled *Ground Water* and *Ground Water Monitoring Review*. Of course, changing the name of any well-known and continuously published journal can present some problems.

By the early 1980s the leading college hydrogeology texts were using the one-word form *groundwater*. Probably the most widely used and referenced hydrogeology text of the 1980s was *Groundwater* (Freeze and Cherry 1979). The second most widely used text, Fetter's (1980) *Applied Hydrogeology*, also used the one-word form. Driscoll (1987) for Johnson Division's second edition of its widely used reference text changed the word form in the text title to *Groundwater and Wells*. Everett's (1980) major work contributing to the new era of environmental hydrogeology was titled *Groundwater Monitoring*. *Webster's Third New International Dictionary and Seven Language Dictionary* (1986) listed the one-word form only. *Webster's II - New Riverside University Dictionary* (1984) recognized both the one- and two-word

forms as did the *Random House Dictionary of the English Language* (1987). *Chamber's Dictionary of Science and Technology* (1983) continued to recognize the two-word form only, as did the *Environmental Glossary* (1984).

The only published discussions that this author was able to locate debating the one-word versus two-word form were in 1986 and 1987 articles published in the journal *Ground Water*. Ivan Johnson, an engineer, strongly opposed the use of the one-word form in his 1986 article, stating that the form was "definitely two separate words." However, Johnson's documentation and citing of sources may have been less than objective or thorough. In his argument, he notes that a "few older editions" of dictionaries had listed the one-word form and he references only those containing the two-word form. He did not list any of those later references that contained the one-word form only. Some of his one-word references also listed the two-word form; for example: *Webster's II New Riverside University Dictionary* (1984).

Alan Freeze (1987), coauthor of the highly recognized text *Groundwater*, responded to Johnson's article in *Ground Water* with an article titled "Groundwater is Probably One Word (Or Maybe Two), More or Less: An Allegory." This highly tongue-in-cheek allegory points out the extreme nonsensical polarity of the issue using two opposing factions he called "Two worders" and "Oneworders." In the allegory, Freeze's Grand Vizier proclaims via poetry a wise position of compromise—the word form "shall be one-and-a-half!" It is illustrative to note that the journal page containing Freeze's article is immediately preceded by the journal's two-word *Ground Water* logo, and is ended by a one-quarter page announcement by the Geology Department at Georgia State University for a short course titled *Groundwater Geophysics*.

2.9 1990s—THE EVOLUTIONARY PROCESS NEARS COMPLETION

Apparently, through the 1980s most reference books converted to the one-word form. So, with the exception of a few 1990s holdouts (including the two aforementioned journals both published by the National *Ground Water* Association), the most widely used noun form has become *groundwater*. The *McGraw-Hill Dictionary of Scientific and Technical Terms* (1994) accepts the one-word form only, as does *The New Encyclopædia Britannica* (1990) and the *Environmental Engineering Dictionary* (1992). The *Encyclopedia Americana* (1993) gives the main listing and description under *groundwater* and a cross reference only to *ground water*. The *Academic Press Dictionary of Science and Technology* (1992) lists *groundwater* first and *ground water* as a second version; the two latter references continue to recognize that both word-forms are acceptable, but say that the one-word form is preferred.

The recent growth of concern for the environment has prompted a spate of books on groundwater and remediation including such titles as *Groundwater Chemicals Desk Reference* (Montgomery and Welkom 1990), *Applied Chemical and Isotopic Groundwater Hydrology* (Mazor 1991), *Applied Groundwater Modeling* (Anderson and Woessner 1992), *Groundwater Treatment Technology* (Nyer 1992), *Permeability and Groundwater Contaminant Transport* (American Society of Testing and Materials 1979), *Migration Processes in the Soil and*

Groundwater Zone (Luckner and Schestakow 1991) and *Practical Techniques for Groundwater and Soil Remediation* (Nyer 1993). Even law treatises such as Tarlock's (1994) *Law of Water Rights and Resources* and Want's (1991) *Law of Wetlands Regulations* defer to the one-word form.

Some continue to use the two-word form almost in defiance of the rest of the scientific and engineering community. Most, however, have agreed that simplicity reduces confusion, and thereby improves communication. Editors for such geological organizations as the American Institute of Professional Geologists now use the one-word form. The *Dictionary of the Earth Sciences* (Stiegeler 1983) and *The Concise Oxford Dictionary of the Earth Sciences* (Allaby and Allaby 1990) both use the one-word form *groundwater* only.

3. LINGUISTICS OF THE WORD

The evolution of words into a more compact form also occurs orally. In fact, changes in pronunciation usually occur before changes in spelling. Spelling conventions are usually conservative and less quick to change. According to Gay Marie Logsdon, Ph.D. in English language and linguistics and coordinator of the Editing Office in the Environmental Sciences Division at Oak Ridge National Laboratory, an oral evolution of the word *groundwater* has already occurred. Her experience suggests that, with few exceptions, most people pronounce *groundwater* as a compound word with primary stress on the first syllable, or root word, and secondary stress on the second syllable. A comparison of a compound vs two separate words could be made by pronouncing:

greenhouse vs *green house*

The compound word is spoken more quickly with primary stress on the syllable *green* and secondary stress on *house*; the two-word form is spoken as two distinct words with a slight pause between the words and with equal stress on both words. Similarly the two versions of *groundwater* can be broken down phonetically:

groundwater = [gráundwàtər] (primary stress + secondary stress + unstress)

ground water = [gráund wátər] (primary stress + pause + primary stress + unstress)

It has been this author's experience that rapid expansion of the public use of certain technical words often accelerates the compounding of those words. People speak the word more frequently, often as an adjective or coupled with other technological words. This seems to result in a slurring or shortening of the pause between the words. For example, in the late 1970s most environmental regulations and dollars expended by the U. S. Environmental Protection Agency (USEPA) were directed at improving facilities for the treatment of municipal *waste water*. The use of the word *waste water* became common, particularly in the engineering community, and soon it was compounded into *wastewater*.

A more recent example of compounding of *water* with other words occurred in the same manner. In the early 1990s the USEPA turned its attention toward environmental problems with *storm water*. Many new regulations directed toward the treatment of *storm water* were developed. Again, engineers responded to the call. As a result, the noun *storm water* has almost evolved into *stormwater*. A recent listing by Lewis Publishers offers ten books on *stormwater* engineering and two books on *storm-water* engineering. Compounding of additional words with *water* has taken place each decade over the past thirty years: *wastewater* in the 1970s, *groundwater* in the 1980s and *stormwater* in the 1990s.

During these evolutionary periods many geologists have sarcastically proposed to the would-be word compounders that a similar logic should be placed on compounding the noun *surface water*. This suggestion has not been well received. One must be careful in making analogies, because the spelling conventions in the English language are conservative and tied to other arbitrary spelling conventions. For example, this author has observed that the spelled form of a single-syllable word often is more readily combined with a following word than is the spelled form of a two-syllable word. Thus, *ground* readily combines with *water*, but *surface*, as a two-syllable word, does not. Note that the single-syllable words *rain*, *sea*, *bath* and *dish* have been compounded with *water* to create the one-word forms *rainwater*, *seawater*, *bathwater*, and *dishwater*, respectively.

Most of the professional community involved in multidisciplinary work for the public has realized that the simplest word form, regardless of pronunciation, provides the easiest guide for consistency within reports. This need for consistency goes beyond the construction of the noun.

4. USE OF THE COMPOUND ADJECTIVE

Use of the one-word form, *groundwater*, as an adjective eliminates the concern for the meaning of the adjective that might arise from its use in the two-word form. Confusion often arises when it is difficult to differentiate what word or words are being modified by a two-word adjective:

“He went on a wild goose chase.” Which was wild, the goose or the chase?

This is usually remedied by hyphenating the two-word form to create a compound adjective:

“He went on a wild-goose chase.” The goose was wild; the chase was not.

The U.S. Government Printing Office (1973) and the U.S. Geological Survey (1978) support the use of hyphens as “a valuable tool in clarifying the meaning of multiple modifiers.” Both organizations note that use of the hyphen is often a matter of opinion, but they also suggest the following (among many other) hyphenations when two words are “combined to form a unit modifier immediately preceding the term modified.” Such as

ground-water study, surface-water study, water-table divide

With rare exception, most nationally recognized hydrologists and hydrogeologists who have, throughout the century, preferred the use of the two-word form for the noun, *ground water*, have used *ground-water* as the companion adjective. The exceptions appear to have been in works produced in the early 1900s by authors such as Mead (1919) or by others who have limited publications on the subject. Pennink used the hyphenated adjective as early as 1905. Review of Meinzer's (1942) text indicates that he always used the adjective *ground-water*, and that the hyphenation process was used in his earlier works (1923). Even soils engineers such as Tschebotarioff (1951) and Peck, Hanson and Thornburn (1953) used the adjective *ground-water*. The most commonly used hydrogeology text prior to Freeze and Cherry (1979) was Davis and DeWiest's (1966) *Hydrogeology*. That text, while it used the two-word noun, hyphenated the word each time it was used as an adjective. Van der Leeden (1971) in preparation of his bibliography of *ground water* hyphenated the adjective. Even Ivan Johnson (1986), who wrote in great opposition to the use of the one-word noun, recognized the appropriate use of the hyphenated modifier, *ground-water*. Oddly, the *Environmental Glossary* (1984) used the one-word form as the adjective but the two-word form for the noun..

Nuhfer and Dalles (1989) in their discussions on the correct use of technical terms state

Every science has its own major reference authority for scientific terms and that authority should be used in place of all others as the final authority. Common 'college editions' of dictionaries are neither complete enough nor updated frequently enough to serve the serious technical writer.

They go on to suggest the importance of the American Geological Institute's (1987) *Glossary of Geology*. All Glossary versions subsequent to the first edition (1972, 1980, and 1987) have recognized both the one- and two-word forms. All versions suggest hyphenating the two-word form when used as an adjective, the latest edition having 38 listings with *ground-water* as the modifier.

5. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that both the one- and two-word noun versions are correct usages, but the evolutionary trend toward the combined word form, *groundwater*, currently dominates and is the preferred use by current textbooks in hydrogeology as well as most references and glossaries. Should one desire to use the two-word noun, *ground water*, then the proper and recommended use of the adjective or modifier is the hyphenated form, *ground-water*. Use of the one-word noun, *groundwater*, with its one-word companion adjective, *groundwater*, eliminates all confusion. Compounding of word forms and condensing them into the simplest possible form is an inevitable process of our language. It does not mean, however, that we have to go overboard with word consolidation, such as the German language where the noun for "field velocity of groundwater" is *Grundwasserfliessgeschwindigkeit* as noted in *Elsevier's Dictionary of Hydrogeology* (1969).

It has been noted that many reports produced by other U. S. Department of Energy contractors and subcontractors are inconsistent in the use of the word forms. Many frequently ignore the appropriate hyphenation of the compound adjective. Some mix different spellings within the same text. Others even change the referenced titles of reports prepared by others by dividing the one-word form into two words. For consistency and clarity, as well as ease of reading and editing, it is suggested that Lockheed Martin Energy Systems, Inc., as the integrating contractor, recommend all internal and external documents regarding U. S. Department of Energy groundwater issues use the preferred one-word form, *groundwater*, for both the noun and adjective and eliminate any further confusion or discussion on this matter.

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