# Chapter 1

## Introduction

### 1.1 Historical Aspect

In the 1970s “environment” became the password, and “silent spring” and “love canal” became the battle cry. It was thought that new protective legislation and money would solve the problem. Unfortunately, there were few scientists available with the proper training to implement the remedial programs financed by Federal and State funding. There resulted an explosion of environmental studies at universities similar to a new program in Alabama at the University of Alabama, the Environmental Institute for Waste Management Studies (EIWMS), which brought together a “think tank” of senior scientists from over the USA with experience in water resources to address the major problems facing local, State and Federal governments. These institutes and programs at universities became a part of the engineering and/or geology departments under the title of environmental studies.

During the 1940s through the 1970s, for example, at the United States Geological Survey (USGS) and the Geological Survey of Alabama and later through activities of newly formed consulting firms with geologists, engineers, chemists, biologists, and botanists, multidiscipline geoscience capabilities in environmental hydrogeology were developed to meet the nation’s needs to solve a complex myriad of problems in the environment, many caused by the industrial revolution brought about by crash programs to produce materials for a world war configration. These programs incorporated a substantial number of professional women, a new element in the work force, who often were able to obtain far more information more easily during the fieldwork stages, particularly well inventories of hydrogeological work than the men.

This book summarizes many of these experiences during this early evolutionary period in the development of the field of environmental hydrogeology in the office as well as during field mapping, data collection, laboratory analyses, test drilling, and surface geophysical and downhole logging. The text includes guidelines for project objectives, purposes, and scope. It includes sample agreements, contracts, data sheets, and forms; itemization of examples of data needed and their compilation; samples of surface and subsurface mapping; types of graphics to illustrate methods of investigation; examples of equipment and supplies that can be used in ground-water investigations; and project scheduling and execution. It includes analysis and cost accounting for completion requirements. There are gaps, unintended, however, hopefully there will be few of these.

During the 1960s, the Alabama headquarters for the Ground-Water Division of the USGS was in an old barracks building behind Smith Hall on the University of Alabama campus. It housed an enthusiastic group of individuals carrying out cooperative ground-water investigations in cooperation with the State Geological Survey of Alabama. Each ground-water project had a component of geologic mapping, water, minerals, and resources evaluation. Methods employed air photography, sedimentation studies, heavy mineral analyses, spring inventories, water analyses, and quantitative testing for a series of cooperative financed reports for each county of the state. Students of the University of Alabama art department developed artwork for illustrations and the covers of reports. The resulting reports published by the Geological Survey of Alabama as bulletins, professional papers, atlases, and special reports converted older more somber traditional reports made more attractive and interesting to the general citizens, business people, and politicians. There resulted a ten-fold increase in sales, and the general public and industry became interested in geology and hydrogeology. This interest was reflected in a very rapid increase in funding and expansion of geoscience work throughout the state.

Within this manual there are a series of comic graphics by Fred Bunnel that illustrate phases of a ground-water investigation. These graphics are included for two purposes: they have been used to help organize and carry out ground-water studies by illustrating the need for proper scheduling and budgeting. They also add a bit of humor. They were developed by Bunnel to illustrate some of the problems that the hydrogeologist confronted in the field.

Finally, the manual recognizes that hydrogeology is a multidisciplinary science, including segments of engineering, physics, chemistry, biology, and botany. As our civilization demands more water for agriculture, commerce, resource development, and urban and domestic supplies, there will become a greater and greater need for knowledge about concepts and methods that will provide the needed information about water resources. It is imperative that we have imaginative, industrious, articulate scientists to convey results of their studies. It is imperative that these professionals also have a practical ability for they must work with well drillers, engineers, citizens, and politicians and be able to communicate with them. They must learn to install water level recorders, rain gages, barometers, recover a tape dropped in a well, repair a malfunctioning motor in a boat, build a monitor well house, or solve a myriad of other practical problems including handling an irate landowner. These are problems that occur everyday in the life of a hydrogeologist. For all of these reasons this manual has been prepared.

It is said that necessity is the mother of invention. This is the case on many occasions when in the early execution of work in district offices of the Ground Water Branch data and specialized equipment and new methods were required. During an early well inventory for example: when preliminary quantitative tests required pumping wells for either a specific capacity or a more detailed analysis. The Alabama district office, using surplus army equipment available after World War II, constructed a trailer mounted, portable, submersible pump. It consisted of an intake hose wound around a makeshift barrel reel. At the flip of a switch it could be lowered into the well and a preliminary pumping test carried out. Installation time was thirty minutes to begin pumping.

Another good example was the training of field geologists to standardize sample collection and description as a part of a geologic field-mapping. Standardization was needed for sand grain size analysis, shape angularity and a color guide. The staff developed a card with standard paint chip samples and with mechanical sand grain analysis equipment, i.e. sieve, shaker, and a meticulous selection of grains were mounted representative grains illustrating grain size, shape, and assortment. These ideas were subsequently developed commercially and sold. When satellite imagery became available, it was immediately applied to well inventory, geologic mapping, special karst studies, seepage loss, vegetation patterns, etc. Early satellite imagery was used in ground-water studies in a report by William J. Powell, district office in Alabama.

These are but a few examples of the need for developing a practical ability by hydrogeologists and engineers in early phases of ground-water work. There are many others, for example, "geobombs" that were developed by Petar Milanovic to study flow rates of ground water in karst. Herb Skibitzke in the USGS Water Resources Division office in Arizona, commandeered a large room, surplus equipment from the air corps and constructed an early 3-D solid-state hydrogeologic computer model. With a modern computer, we now can carry more computation power on our wrists; however, Skibitzke's computer for ground water quantitative studies was a first.

Some of the more imaginative staffs in the district offices developed laboratory and field techniques; for example, the paint chips became more scientific color charts for standardization of lithologic characteristics; sand grain samples became sand grain charts; later both were commercialized and used as a standard means of sample descriptions. Field chemistry laboratory kits were gradually updated to sophisticated laboratory analysis; and eventually, data recording evaluation and recovery evolved from computer capabilities. Portable pumping equipment was invented. Geophysical downhole logging became standard practice. Sequential air photography and satellite imagery became readily available and with these changes the character of geologic mapping, well inventory, pumping tests, geochemical studies, and report preparation change remarkably.

This book was born out of experience from work beginning in 1943 with the Ground-Water Branch (GWB) of the United States Geological Survey (USGS). This was an early period represented by studies of the geology, source, occurrence, and movement of ground water in the United States by the USGS. During this period of ground-water investigations, employees of the Water Resources Division Ground-Water Branch were under the supervision of Dr. O. E. Meinzer, who is considered the "Father of Ground Water" in the United States and one of the early ground-water scientists in the world. His Water Supply Papers 489 and 494 – *Ground-water resources of the United States* were used as a textbook for the early generations of hydrogeologist. In the 1940s, 1950s and 1960s, the Water Resources Division implemented ground-water schools at different district offices twice a year to provide training for its staff of geologists, engineers, and chemists. In these early training schools Gerry Parker was known as the "Professor of Hydrological Knowledge". These were reorganized into two-week courses at elementary and graduate level and eventually were developed into a formal program given at the USGS Denver Federal Center. Initially, there were ground-water notes and special publications supplied by leaders and professors that included C. V. Theis, Stan Lohman, C. E. Jacobs, Hilton Cooper, Bob Bennett, Bob Brown, John Ferris, Ivan Johnson, and others. Subsequently, the notes from these early lectures were formalized in two special Water Resources Series 1536–1544. The more formal training program at the Denver Federal Center with class and lecture rooms and laboratories was expanded to include a select group of international students as well as representatives from other Federal and State agencies.

It would be unacceptable to omit the fact that the early hydrogeologists learned and borrowed many techniques and equipment from the oil patch. Author LaMoreaux spent weeks with representatives of major oil companies in the field and laboratory learning methods applied to surface exploration, test drilling, sample description, well construction practices, and surface geophysical methods that could be applied to ground-water studies. This experience was combined with many days working with water well drillers, learning the practical aspects of development of ground water from wells. These methods were implemented in the Alabama district office of the USGS while working closely together with geologists of the Geologic Division – Watson Monroe, L. W. Stephenson, F. Stearnes McNeal, Hoye Eargle, Lewis Conant, and State Geologists Bob Vernon, Lyman Tolman, Furcron and others. This experience illustrated dramatically the importance of understanding the geology, structure, stratigraphy, and depositional environments as related to determining the recharge, source, and occurrence of ground water.

Hundreds of talks on geoscience and in particular water resources to elementary, high school, college, civic clubs, and social and political groups, plus teaching hydrogeology at the university for nearly 20 years, has illustrated the necessity for graphic communication about geology and hydrogeology. Clear, precise, and carefully prepared graphics were needed: photographs, columnar sections, cross sections, fence diagrams, and 3-D models. Information that the student, lay public, and politician can understand were required. There also became a need for adequate graphic material for courtroom testimony and a whole new field of communication has developed.

Finally, geoscientists are not generally known for their administrative capabilities. In the early history of ground-water studies, projects were often contracted with little planning of purpose, scope, objectives, cost, or accountability. These techniques for planning had to be borrowed from administrative procedures developed in business and commerce. Early hydrogeologic projects without proper planning and scheduling resulted in hundreds of reports overdue, over-budgeted, missed deadlines, and limited use. Many of these reports sit on shelves rarely used. Some of the basic techniques related to management are included in this manual.

## 1.2 Concept of Environmental Movement

In the 1970s the environmental movement resulted in State and Federal regulations to establish restrictions for location of hazardous waste and municipal, solid waste landfills. Regulations require owners/operators to demonstrate that the hydrogeology has been completely characterized at proposed landfills, and that locations for monitoring wells have been properly selected. Owners/operators are also required to demonstrate that engineering measures have been incorporated in the design of the municipal solid waste landfills, so that the site is not subject to destabilizing events, as a result of location in unstable areas.

The complexity of hydrogeologic systems, mandates thorough hydrogeologic studies to determine whether a specific site is, or can be rendered, suitable for a land disposal facility. Important components of hydrogeologic studies are field mapping of structural and stratigraphic units; interpretation of sequential aerial photographs; test drilling and geophysical analysis; fracture analysis; seasonal variation in water within aquifers; determination of control for recharge, and local base level; and evaluation of the effects of man's activities, such as pumping, dewatering and construction.

Consequently, for example the siting landfills involves collection of information necessary to answer a few questions, including those that follow: (1) Will the natural hydrogeologic system provide for isolation of wastes, so that disposal will not cause potential harm or the environment? (2) Is the site potentially susceptible to destabilizing events, such as collapse or subsidence, which will produce a sudden and catastrophic release of contaminants? (3) Will contaminants, if released from the facility, or rapidly and irrevocably transmitted to important aquifers or bodies of surface water? (4) Are the monitoring wells in proper positions to intercept ground-water flow from the facility? (5) If minor releases (leakage) occurs, will contaminants be readily detected in monitoring wells? (6) If a release is detected, is knowledge of the hydrogeologic setting sufficient to allow rapid and complete remediation of a release? (7) Is the hydrogeologic system sufficiently simple to allow interception and remediation of contaminated ground water?

Answers to the above questions depend upon the thoroughness of hydrogeologic studies, by which each site must be assessed and evaluated, prior to construction of a land-disposal facility. In the experience of the authors, most significant environmental problems, resulting from releases from land disposal facilities, occur from facilities for which preliminary, hydrogeologic studies were inadequate to answer the above questions. In many such cases, studies, designed to gain understanding of the hydrogeologic system, did not begin until after a release was detected. Compliance monitoring, "plume chasing" and remediation of ground water are costly processes, all of which can be avoided by assiduous care in selection of propre sites for land disposal.

In practice, the conceptual hydrgeologic model will be modified and improved as studies progress at the selected site. The final model should provide an accurate integration of the geologic, hydrogeologic, and geotechnical characteristics on the site that has been tested by installation of borings, piezometers and monitoring wells, measurement of water levels, and determination of the direction and rate of ground-water flow. The knowledge and understanding represented by the hydrogeologic model, and the data necessary to derive the model, serve to demonstrate suitability of the site and provide the basis for the final engineering design of the landfill.

## 1.3 Environmental Aspects of Karst Terrains

Some special attention is required for areas underlain by karst or areas underlain by limestone, dolomite, or gypsum or salt type of rocks, These regions constitute about 25% of the land surface of the world and are a source of abundant water supplies, minerals, and oil and gas.

Because of the complexity of karst systems, the concepts related to the movement and occurrence of ground water in karst, methods of exploration and development of water, safe engineering practices in construction of all kinds, and adequate environmental safety precautions cannot be based on one uniform set of rules.

The impact of karst terrains is great on humans and of substantial interest financially. This is documented by select references from recent publications. John Newton (1984) *Development of Sinkholes Resulting From Man's Activities in the Eastern United States* (19 states) reports that since 1950 there have been more than 6 500 sinkholes or related features that have occurred. Newton further states that the total cost of damage and associated protective measures resulting from these induced sinkholes is unknown, however, at 5 dam sites alone repair costs were in excess of U.S.$140 million. In a report of the U.S. National Research Council (1991) *Mitigating Losses from Land Subsidence in the United States* was reported that 6 states have individually sustained U.S.$10 million or more from damages from the cause.

Karst areas are dynamic as well as environmentally sensitive. The geologic structure, solubility of the rocks involved, and climatic conditions determine, to a great degree, how rapid changes can take place. Therefore, karst investigations must consider the dynamic nature of karst.

The USGS and some state surveys in the USA have special reports on karst areas. For example, the Illinois State Geological Survey has published *Karst Map Projects to Aid Ground Water Regulators* in their Summer 1994 issue of *GeoNews* (GeoNews 1994).

Other State Geological Surveys around the world have released similar materials.

In other countries, for example the GSI Ground-water Newsletter of the Geological Survey of Ireland presents guidelines for ground-water development, their problems and solutions in karst areas, preparing ground-water vulnerability maps and reports (Geological Survey of Ireland 1994). In England, reports relate *Research on Radon in British Limestone Caves and Mines, 1970–1990* (Gunn et al. 1991), and *Protecting Cumbria's Limestone Pavements* (Cumbria County Council 1993). In the western Ukraine, regulations are being developed for karst terrains, environmental changes, and human impact (1993).

Since the 1970s, the environmental movement in the USA has progressed from adolescence to maturity. The Resource Conservation and Recovery Act (RCRA) and Comprehensive Emergency Compensation and Liability Act (CERCLA) were enacted.

The range of environmental issues are diverse and encompass local, regional, and global problems involving pesticides and toxic substances, hazardous and solid waste disposal, water quality and quantity, urban and rural air pollution, resource use and management, soil erosion and stability, degradation of aquatic and terrestrial ecological systems, marine pollution, loss of biological diversity, and climate change.

Federal laws in the USA that protect ground-water statutes in the USA include:

- Clean Water Act
- Safe Drinking Water Act
- Clean Air Act
- Comprehensive Environmental Response, Compensation and Liability Act
- Federal Insecticide, Fungicide, and Rodenticide Act
- Toxic Substances Control Act
- Coastal Zone Management Act
- Endangered Species Act
- Magnuson Fisheries Act
- Resources Conservation Recovery Act
- Forest Land Management Planning Act
- Renewable Natural Resources Planning Act
- Disaster Relief Act
- Marine Plastics Pollution Research and Control Act
- Marine Protection, Research and Sanctuaries Act
- Ocean Dumping Ban Act
- Shore Protection Act
- National Earthquakes Hazards Reduction Act
- Energy Act
- Global Climate Change Protection Act
- Global Change Research Act
- Oil Pollution Act
- National Environmental Policy Act
- Weather Service Modernization Act
- Federal Emergency Management Act

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