



Designation: D 6036 – 96 (Reapproved 2002)

Standard Guide for Displaying the Results of Chemical Analyses of Ground Water for Major Ions and Trace Elements—Use of Maps¹

This standard is issued under the fixed designation D 6036; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide offers a series of options but does not specify a course of action. It should not be used as the sole criterion or basis of comparison and does not replace or relieve professional judgment.

1.2 This guide covers methods that display, as mapped information, the chemical constituents of ground-water samples. Details required by the investigator to use fully the methods are found in the listed references.

1.2.1 The use of maps to display water-quality data are a common technique to assist in the interpretation of the chemistry of water in aquifers, as the areally distributed values can be easily related to the physical locality by the investigator.

1.2.2 The distribution in an aquifer of chemical constituents from two water sources or of liquids of different densities may be difficult to illustrate explicitly on a two-dimensional map because of stratification in the third dimension. Also, the addition of a vertical cross section may be required (see 4.4).

1.3 Many graphic techniques have been developed by investigators to assist in summarizing and interpreting related data sets. This guide is the fourth document to inform the hydrologists and geochemists about traditional methods for displaying ground-water chemical data.

1.3.1 The initial guide (Guide D 5738) described the category of water-analysis diagrams that use pattern and pictorial methods as a basis for displaying each of the individual chemical components determined from the analysis of a single sample of natural ground water.

1.3.2 The second guide (Guide D 5754) described the category of water-analysis diagrams that use two-dimensional trilinear graphs to display, on a single diagram, the common chemical components from two or more analyses of natural ground water.

1.3.3 The third guide (Guide D 5877) presented methods that graphically display chemical analyses of multiple ground-water samples, discrete values, as well as those reduced to comprehensive summaries or parameters.

1.4 Notations have been incorporated within the illustrations of this guide to assist the user in understanding how the maps are constructed. These notations would not be required on a map designed for inclusion in a project document.

NOTE 1—Use of trade names in this guide is for identification purposes only and does not constitute endorsement by ASTM.

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 ASTM Standards:

- D 596 Guide for Reporting Results of Analysis of Water²
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids³
- D 1129 Terminology Relating to Water²
- D 5254 Practice for Minimum Set of Data Elements to Identify a Ground-Water Site³
- D 5408 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part One—Additional Identification Descriptors³
- D 5409 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part Two—Physical Descriptors³
- D 5410 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part Three—Usage Descriptors³
- D 5474 Guide for Selection of Data Elements for Ground-Water Investigations³

¹ This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved Oct. 10, 1996. Published June 1997.

² *Annual Book of ASTM Standards*, Vol 11.01.

³ *Annual Book of ASTM Standards*, Vol 04.08.

D 5717 Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured Rock Aquifers⁴

D 5738 Guide for Displaying the Results of Chemical Analyses of Ground Water for Major Ions and Trace Elements—Diagrams for Single Analyses⁴

D 5754 Guide for Displaying the Results of Chemical Analyses of Ground Water for Major Ions and Trace Elements—Trilinear Diagrams for Two or More Analyses⁴

D 5877 Guide for Displaying the Results of Chemical Analyses of Ground Water for Major Ions and Trace Elements—Diagrams Based on Data Analytical Calculations⁴

3. Terminology

3.1 *Definitions*—All definitions are in accordance with Terminology D 653. Additional definitions that relate to this guide can be found in Guide D 596, Terminology D 1129, and Guides D 5738, D 5754, and D 5877.

4. Significance and Use

4.1 Each year many thousands of water samples are collected and the chemical components are determined from natural and human-influenced ground-water sources.

4.2 The objective interpretation of the origin, composition, and interrelationships of water can be simplified by displaying the distribution of the constituents and related parameters on areal maps (1,2).⁵

4.2.1 The origin of the chemical composition of the water may be postulated by the amount and the distribution of the constituents as shown on the maps.

4.2.2 The chemical composition of the water can be scrutinized for distinct characteristics and anomalies by use of the maps.

4.2.3 The interrelationships of the water chemistry from various sampling locations can be visualized on the maps.

4.3 This guide presents various mapping methods for showing distribution of chemical constituents using areal and time-related trends; maximum, minimum, or mean values; and relationships between chemical and associated parameters.

4.4 Exercise caution when interpreting the distribution of chemical constituents on two-dimensional (*X* and *Y*) maps as liquids of different densities tend to stratify in the third dimension (*Z*).

NOTE 2—Water (or other liquid) with a relatively low concentration of dissolved solids (or of a low relative density) normally will float on top of water with high dissolved solids or a liquid of higher density (3–7). A naturally occurring example is an island surrounded and underlain by sea water where rain water falling on the island forms a fresh water lens above the underlying sea water. Where the presence of liquids of different densities are evident in a mapped area, cross sections of the aquifer assist in showing the vertical (*Z*) distribution of the chemical constituents or a pattern can be used on the map to delineate the extent of this water.

NOTE 3—Immiscible liquid contaminants, such as petroleum products, with a relative density less than that of the water will float on top of the

water. Liquids that are more dense than water will flow to the bottom of the aquifer. Miscible liquids, such as sea water, mix with the fresher water creating a zone of dispersion at the interface of the two liquids.

4.5 Aquifers in fractured rock or karst areas may result in noncontinuum conditions for the chemical parameters in the water (Guide D 5717). This guide assumes the aquifer usually consists of an equivalent porous media.

4.6 This is not a guide for the selection of a map technique for a distinct purpose. That choice is program or project specific.

NOTE 4—For many hydrochemical research problems involving the scientific interpretation of ground water, the areal map is only one segment of several methods needed to interpret the data.

5. Selection and Preparation of Data for Plotting on Areal Maps

5.1 *Minimum Data Requirements:*

5.1.1 In order to position accurately the ground-water quality collection locations on two- and three-dimensional maps, a minimum set of data elements must be known for each site. Refer to Practice D 5254, and Guides D 5408, D 5409, D 5410, and D 5474 for guidance in selecting the appropriate assortment of information.

5.1.2 A basic requirement for the analytical methods described in this guide is that the samples be selected randomly or of a systematic sampling strategy, and of sufficient number and distribution to represent the sampled population to allow for the construction of a meaningful map.

NOTE 5—A truly random sample is impractical, as ground-water samples are from a subsurface population that only can be obtained from sources that intersect the water table, for example, wells, springs, tunnels, or caves. These sources are not likely to be distributed randomly in three-dimensions throughout an aquifer. A more refined picture of the entire population, however, is possible as the size of the random sample is increased (8).

5.2 *Recommended Checks for Accuracy of Data Parameters:*

5.2.1 To avoid errors, all of the chemical analyses used for the mapping methods described in this guide must be verified properly.

5.2.1.1 Noncontinuum concentrations or possible erroneous values in a data set (sample) become more apparent when using mapping methods, as these appear as extreme values on the maps.

5.2.1.2 Erroneous values that fall in the same numerical range as a typical value in the data set are difficult to detect but are most likely found by a complete validation of the data set (sample) against the original data source.

NOTE 6—To reduce the chance of incorporating erroneous numbers on the map displays, the original chemical analyses and related data must be previewed carefully as to proper collection and analytical procedures. In addition, care must be taken to ensure that none of the numbers have been transposed during transcription of the data. Completely automated data collection and transcription procedures help to eliminate data errors.

5.2.2 For those analyses where all of the major chemical ions in the ground water are determined, a check of the chemical balance should be made to help in the detection of data errors (see Guides D 5738, D 5754, and D 5877).

⁴ Annual Book of ASTM Standards, Vol 04.09.

⁵ The boldface numbers in parentheses refer to the list of references at the end of this guide.

6. Ground-Water Quality Maps

6.1 Introduction—This guide provides methods that furnish helpful map displays of the results of chemical analyses of water samples. These methods include procedures that display the distribution of a single constituent for a discrete period, the areal change of a constituent concentration over a period, and the relationship of two or more parameters from each analysis for the map area.

6.2 Maps of a Single Chemical Constituent for a Discrete Time—These maps display the areal distribution of a single ion in an aquifer or within a project.

6.2.1 Distribution of an Ion by Sized Symbols—A simple map is valuable for showing collection sites for areas of limited data or a complex distribution of chemical constituents. Fig. 1 shows the values of the constituent symbolized by the size of a solid circle (9).

6.2.2 Distribution of a Compound by Equal Concentration Lines—A two-dimensional map of a compound or ion in a homogeneous aquifer is shown by Fig. 2 where the value and distribution of the constituent is represented by equal lines. This map shows the distribution of volatile organic compounds (VOC) resulting from spills in a developed area (10).

6.2.3 Distribution of an Ion Emphasized by Shaded Concentration Areas—Maps that use shaded concentration or colored areas visually point out areas of interest to the project (Fig. 3). The shaded area can be used to highlight either high or low concentrations, for example, the maximum chloride ion (11).

6.2.4 Distribution of an Ion in Waters from Multiple Sources—The distribution of a constituent in water from two or more sources, for example, fresh water and sea water, and in a homogeneous aquifer, is shown by Fig. 4. This map shows the position of the saltwater-freshwater interface and the distribution of the chloride constituent. The saltwater wedge is moving north toward an area of withdrawal and into the area of

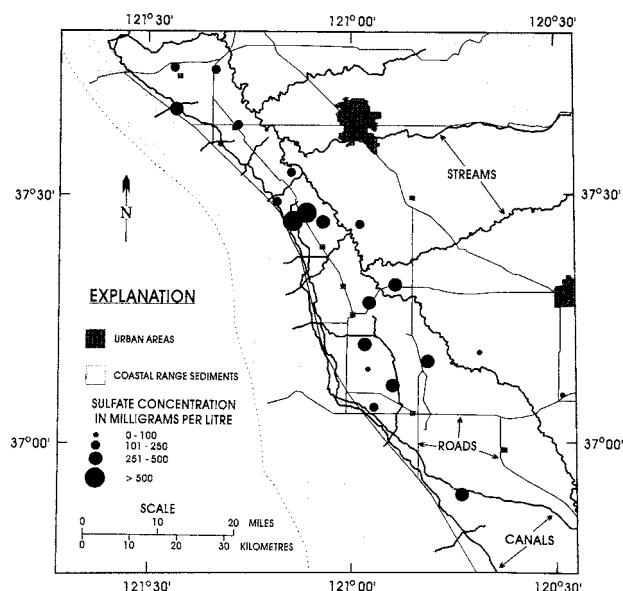


FIG. 1 Map Showing Data Values by Sized Symbols [Adapted from Ref (9)]

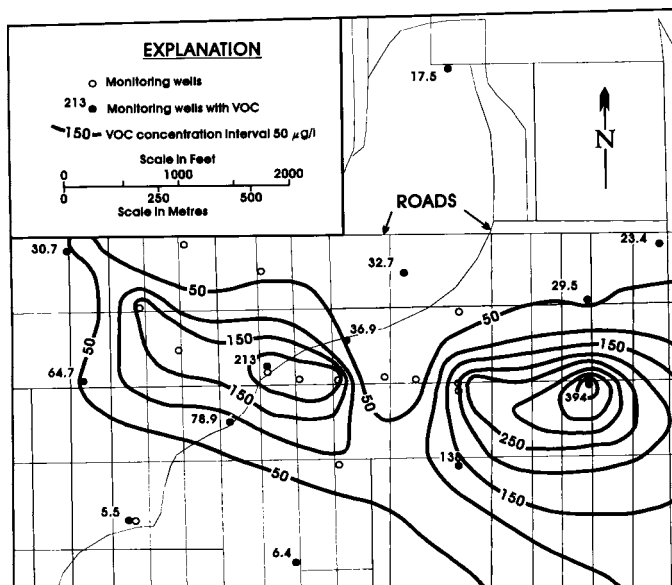


FIG. 2 Map Showing Lines of Equal Total VOC Concentration [Adapted from Ref (10)]

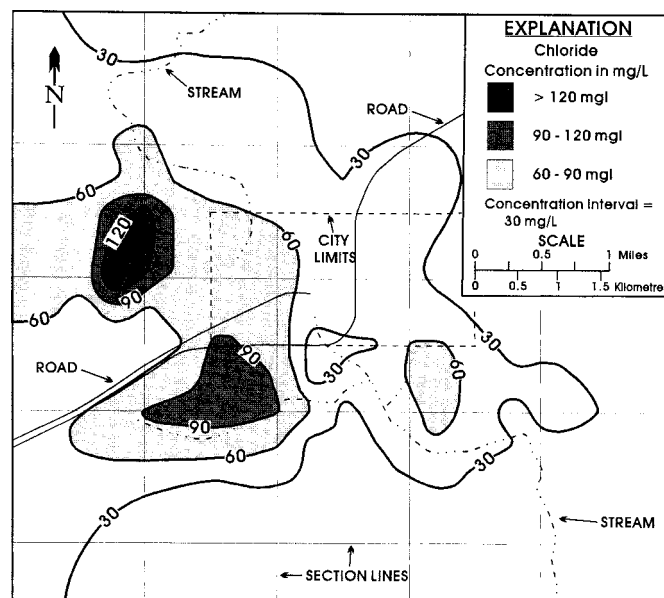


FIG. 3 Map of Shaded Areas of Chloride Concentration [Adapted from Ref (11)]

the aquifer that contains freshwater. The north edge of the saltwater wedge is at the base of the freshwater (12).

6.2.5 Shaded or Colored Concentration Map and Matching Vertical Cross Section—The addition of a cross section with the concentration map improves the understanding of the vertical distribution of a liquid containing the constituent (Fig. 5). Usually a liquid with a density significantly different than the natural water in the aquifer will stratify the level depending upon the density of the invading liquid (see 4.4) (13).

6.2.6 Ion Distribution in Water Infiltrating from a Surface Source—Other types of maps show the results of surface facilities, such as streams or constructed pits, intersecting the