INTRODUCTION

The quality of ground water is of concern to all. Based on 1975 water-use data in the State of Washington (Dion and Lum, 1977), ground water makes up about 34 percent of all water used by municipal water systems, about 22 percent used by industry, and about 5 percent used for irrigation. In addition, approximately 500,000 rural residents of Washington depend on good quality ground water for household use.

The Washington State Department of Ecology (DOE), in order to carry out its water-quality-management responsibilities, and the Washington State Department of Social and Health Services (DSHS), whose rules and regulations govern use of water for human consumption, require information on ground-water-quality characteristics and the availability of ground-water-quality data throughout the State. Hence, the U.S. Geological Survey (USGS), under an agreement with DOE, assembled the existing data for the State of Washington concerning the concentration of fluoride, nitrate, and dissolved solids in ground water. These constituents are included among those commonly used to determine the suitability of water for drinking; they also reflect both natural and man-imposed effects on water quality and, if present in excessive concentrations, can limit the utility of water. Coincidentally, data on fluoride, nitrate, and dissolved-solids concentrations are the most plentiful of ground-water-quality data available for the State of Washington. Ground-water data on a broad, areal basis are scarce for trace metals, bacteria, and organic constituents. Even if this report shows that fluoride, nitrate, or dissolved-solids concentrations in ground water at a particular place does not exceed U.S. Environmental Protection Agency (EPA) regulations (1977a,b), the suitability of water for drinking is not assured.

Data were used from four sources: USGS, DSHS, EPA, and Battelle Pacific Northwest Laboratory. The USGS and EPA data include those collected from other sources, primarily other federal and state agencies. It is estimated that approximately 90 percent of the available nitrate, fluoride, and dissolved-solids concentration data for ground water in the State of Washington are represented in the results of this study.

Data from sources other than the USGS were plotted on the accompanying maps only when there was a lack of USGS data for specific constituents and areas. Thus, for example, for the lower Yakima River basin where there was a large amount of USGS data for nitrate concentration in ground water, only the USGS data appear on the map. Data from other sources would not have increased the reliability or utility of the maps in that particular area. Where there were multiple analyses for fluoride, nitrate, or dissolved solids from one well, only the symbol representing the highest concentration of each constituent was plotted on the appropriate map. No attempt was made to determine trends in concentrations with time.

Data on fluoride and nitrate concentrations were available from all sources in both dissolved and total (dissolved plus suspended) forms. Where data on dissolved fluoride and/or nitrate were available, the total-concentration data were not plotted on the accompanying maps. If limited data (or no data) on the dissolved fluoride and/or nitrate concentrations were available for specific locations, then the total-concentration data were plotted. Nitrite concentration was assumed to be negligible and nitrite-plus-nitrate concentration data was treated as nitrate alone.

Most values plotted for dissolved solids are those commonly referred to as total dissolved solids (TDS). Where no other data were available, total solids (dissolved plus suspended) were plotted. Values of total solids that were plotted ranged from 500 to 700 milligrams per liter (mg/L).

The data are presented on maps that are divided into the principal ground-water region designations of Molenaar, Grimstad, and Walters (1980). Data were divided relative to EPA drinking-water standards into three groups as follows: sites where concentrations are less than established standards; sites where concentrations exceed standards by up to two times; and sites where concentrations are greater than twice the established standards.

DISTRIBUTION OF AVAILABLE DATA

Of the 21 principal ground-water regions, representative data are available for four: the Puget Sound, Yakima, Spokane, and Columbia Basin regions. Data are lacking only in small sections of these regions that also correspond with areas of low population density. In these ground-water regions generalizations can be made about ground-water quality on a regional basis with a fairly high degree of confidence.

For several ground-water regions, the majority of data come from near population centers, usually around major rivers or lakes, or in coastal areas, but many areas within these regions have little or no available data. Included are the Willapa, Chehalis, Olympic Peninsula, Cowlitz, and Lewis regions in western Washington, and the Entiat-Wenatchee, Chelan, Okanogan, Northeastern, and Walla Walla-Tucannon regions in central and eastern Washington. Additional data are needed before broad generalizations can be made about the ground-water quality in these regions.

The remaining ground-water regions, the Grays-Elochoman and San Juan in western Washington and the Klickitat, Horse Heaven, Methow, Palouse, and Blue Mountains in central and eastern Washington, have a limited number of chemical analyses of ground water from within their boundaries. The available analyses are restricted to population centers (towns or agricultural areas) or are widely spaced throughout the region. Data are not adequate to make any generalizations about ground-water quality, except on a local basis. Generally, these regions have lower population densities.

DRINKING-WATER REGULATIONS

The U.S. Environmental Protection Agency has established "maximum contaminant levels" for public-drinking water. These include both mandatory and recommended concentration limits for many common and uncommon chemical constituents. The mandatory limits (Primary Drinking Water regulations, U.S. Environmental Protection Agency, 1977a) are required for the protection of public health. The recommended limits (Secondary Drinking Water Regulations, U.S. Environmental Protection Agency, 1977b) apply generally to the aesthetic characteristics of the water and are not related to public health concerns. The Primary and Secondary Drinking Water Regulations are referred to collectively in this report as Drinking Water Regulations (DWR).

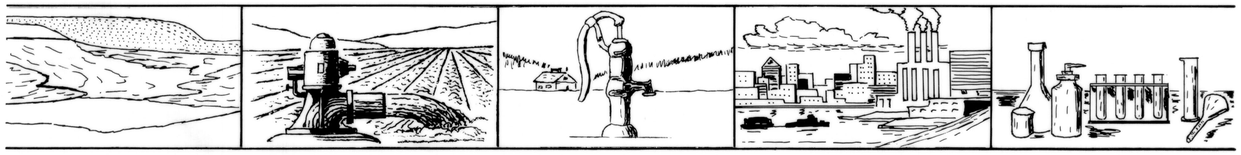
The mandatory DWR limits for fluoride and nitrate concentrations are as follows: fluoride, 1.8 mg/L in eastern Washington and 2.0 mg/L in western Washington (dependent on annual average of maximum daily air temperature), and nitrate, 10.0 mg/L (when reported as N). The recommended DWR limit for dissolved-solids concentration is 500 mg/L.

AREAS WHERE DATA EXCEED DRINKING-WATER REGULATIONS

Based on the available ground-water-quality data (limited data in some areas), some generalizations can be made about the areas where concentrations of fluoride, nitrate, and dissolved solids exceeded DWR levels.

Fluoride

Fluoride concentrations in the ground water of Washington exceeded DWR levels in about 1 percent of the wells examined for this report. (Not all of these analyses are plotted on the accompanying map due to instances where several closely spaced wells are represented by one symbol.) Approximately 5 percent of the high concentrations are found in widely separated (isolated) wells and are apparently the result of local, natural geohydrologic conditions. The remainder are in two areas: the Columbia Basin region and the Hanford Facility in the Yakima region. High concentrations of fluoride in ground water in the Columbia Basin and in the Hanford Facility are apparently the result of natural conditions in the deeper basalt aquifers tapped by many wells in those regions.



Principal ground-water region (Molenaar, Grimstad, and Walters, 1980)	Primary aquifer material (after Molenaar, Grimstad, and Walters, 1980)	Water use (1975 ground-water use only, Dion and Lum, 1977) Annual (millions of gallons)	Irrigation (percent of annual water use)	Municipal (percent of annual water use)	Industrial (percent of annual water use)	Occurrence of fluoride, nitrate, and dissolved-solids concentration levels in excess of Drinking Water Regulations (U.S. Environmental Protection Agency, 1977a and 1977b) within each ground-water region	Source of high levels of fluoride, nitrate, and dissolved-solids concentrations in excess of Drinking Water Regulations
Grays-Elochoman Region	Alluvium and basalt	106	100.0	[a]0.0	[a]0.0	None[c]	Not applicable
Willapa Region	Alluvium and older sedimentary deposits	1,070	45.1	35.6	19.3	None[c]	Not applicable
Chehalis Region	Alluvium, glacial drift deposits, and older sedimentary deposits	2,890	75.0	21.2	3.8	Dissolved-solids concentrations in water from seven wells and nitrate concentrations in water from five wells exceeded DWR levels.	A localized problem in a small part of the region. Possibly due to lateral or vertical migration of connate ground water into an aquifer caused by pumping.
Olympic Peninsula Region	Alluvium, glacial drift, and older sedimentary deposits	2,000	46.9	38.7	14.4	Dissolved-solids concentrations in water from five wells in the coastal areas exceeded DWR levels.	A localized problem in some coastal areas only, possibly due to incipient seawater intrusion.
San Juan Region	Glacial drift	17	[a]0.0	100.0	[a]0.0	Dissolved-solids concentration in water from one well in the coastal area exceeded DWR levels.	A localized problem in some coastal areas only, possibly due to incipient seawater intrusion. Seawater intrusion may be more widespread than these data suggest (Dion and Sumioka, written commun., 1980).
Puget Sound Region	Alluvium and glacial drift	54,900	23.8	56.2	20.0	Fluoride and nitrate concentrations in water from a few widely separated wells exceeded DWR levels. Dissolved-solids concentrations in water from 23 wells primarily in the coastal areas exceeded DWR levels.	Several small areas having high concentrations of fluoride, nitrate, and dissolved solids indicate localized water-quality problems only, for example, incipient seawater intrusion in a few small coastal areas (Dion and Sumioka, written commun., 1980).
Cowlitz Region	Alluvium and older sedimentary deposits	308	[a]0.0	100.0	[a]0.0	Dissolved-solids concentration in water from one well exceeded DWR levels.	A localized problem that may be due to the movement of connate ground water, as described above for the Chehalis Region.
Lewis Region	Alluvium and older sedimentary deposits	33,800	15.7	17.9	66.4	None[c]	Not applicable
Klickitat Region	Alluvium and basalt	2,590	98.5	1.5	[a]0.0	None[c]	Not applicable
Horse Heaven Region	Alluvium and basalt	9,360	71.1	.3	28.6	Nitrate concentration in water from one well and fluoride and dissolved-solids concentrations in water from two wells exceeded DWR levels.	Isolated instances of naturally occurring high concentrations of dissolved solids and fluoride, common in deep wells tapping basalt aquifers.
Yakima Region	Alluvium, glacial drift, older sedimentary deposits, and basalt	16,300	18.9	41.9	39.2	Fluoride concentrations in water from two wells located within the Hanford Department of Energy Facility exceeded DWR levels. Dissolved-solids concentrations in water from 18 wells principally in the south-central part of the Yakima region near Prosser and within the boundaries of the Hanford Facility exceeded DWR levels, four of them by more than twice. Nitrate concentrations in water from numerous wells, principally in the south-central Yakima region near Mabton, and within the boundaries of the Hanford Facility, exceeded DWR levels, at least 20 of them by more than twice.	Naturally occurring high fluoride concentrations are common in deep wells tapping basalt aquifers. High nitrate and dissolved-solids concentrations in the south-central Yakima region near Prosser are probably due to natural conditions or extensive long-term agricultural development and irrigation. In the Hanford Facility, high nitrate and dissolved-solids concentrations are probably the result of manmade changes in ground-water chemistry.
Entiat-Wenatchee Region	Glacial drift and basalt	927	[a]0.0	69.7	30.3	Nitrate concentration in water from one well and dissolved-solids concentrations in water from two wells near Wenatchee exceeded DWR levels.	Isolated occurrences of high nitrate and dissolved-solids concentrations are probably due to natural conditions.
Chelan Region	Alluvium and glacial drift	[b]0	--	--	--	None[c]	Not applicable
Methow Region	Alluvium and glacial drift	815	81.7	18.3	[a]0.0	None[c]	Not applicable
Okanogan Region	Glacial drift and basalt	5,000	23.6	29.2	47.2	Dissolved-solids concentrations in water from four wells in the Okanogan River valley exceed DWR levels.	Isolated occurrences of high dissolved-solids concentrations are probably due to natural conditions.
Northeastern Region	Alluvium and glacial drift	2,290	48.4	46.4	5.2	None[c]	Not applicable
Spokane Region	Alluvium, glacial drift, and basalt	45,900	34.0	58.7	7.3	Fluoride and dissolved-solids concentrations in water from two wells and nitrate concentrations in water from six wells exceeded DWR levels.	Isolated high fluoride and dissolved-solids concentrations are probably due to natural conditions, and high nitrate concentrations are probably the result of natural conditions or unsewered, densely populated areas.
Palouse Region	Alluvium and basalt	5,970	56.2	43.6	.2	Nitrate concentrations in water from eight widely separated wells exceeded DWR levels.	Widely separated occurrences of high nitrate concentrations are probably due to natural conditions.
Columbia Basin Region	Alluvium, glacial drift, and basalt	37,500	67.0	18.6	14.4	Nitrate concentrations in water from 20 wells, dissolved-solids concentrations in water from 22 wells, and fluoride concentrations in water from 14 wells exceeded DWR levels.	Widely separated occurrences of high fluoride, dissolved-solids, and nitrate concentrations are probably due to natural conditions.
Walla Walla-Tucannon Region	Alluvium, older sedimentary deposits, and basalt	7,120	46.2	42.2	11.6	The nitrate concentration in water from one well, fluoride concentrations in water from three wells, and dissolved-solids concentrations in water from two wells exceed DWR levels.	Isolated occurrences of high fluoride, nitrate, and dissolved-solids concentrations are probably due to natural conditions.
Blue Mountains Region	Basalt	1,040	27.8	71.7	.5	None[c]	Not applicable

[a]Less than 0.1 percent.
[b]Less than 1 million gallons based on available data.
[c]No values of fluoride, nitrate, and dissolved-solids concentration exceeded Drinking Water Regulations.

Nitrate

Nitrate concentrations in the ground water of Washington exceeded DWR levels in about 3 percent of the wells examined for this report. Approximately 15 percent of the high concentrations are found in widely separated wells throughout the State. The remainder are in five general areas: the lower Yakima River basin and Hanford Facility of the Yakima region and parts of the Spokane, Palouse, and Columbia Basin regions. High concentrations of nitrate in these areas generally occur in wells tapping shallow aquifers consisting of alluvium, glacial drift, older sedimentary deposits, or basalt.

High concentrations of nitrate are generally the result of (1) natural conditions; (2) agricultural development of the area (irrigation may leach certain soluble materials from the soil that may increase nitrate concentrations in the ground water); or (3) densely populated, unsewered areas having highly permeable soils that allow septic-tank effluent to infiltrate the ground-water system. In the Hanford Facility area, where high nitrate concentrations have been studied in detail, they are mostly a result of infiltration of industrial and sanitary waste water from various operations in the Facility (Lindberg and Bond, 1979).

Dissolved Solids

Dissolved-solids concentrations in the ground water of Washington exceeded DWR levels in about 3 percent of the wells examined for this report. Approximately 5 percent of the high concentrations are found in widely separated wells and are apparently the result of local, natural geohydrologic conditions. The remainder are in two general areas: the Chehalis, Olympic Peninsula, and Puget Sound regions of western Washington and the Yakima and Columbia Basin regions of eastern Washington.

High concentrations of dissolved solids in the ground water of parts of the Olympic Peninsula and Puget Sound regions are apparently the result of natural conditions common to the glacial-drift and alluvial aquifers or possibly of incipient seawater intrusion. In the Chehalis region, high concentrations of dissolved solids may result from pumping out of a part of the aquifer that has been intruded by connate water from older and deeper continental- and marine-sedimentary deposits.

In the lower Yakima River basin and the Columbia Basin region, high concentrations may be the result of either natural conditions or the extensive, long-term agricultural development of the area. Within the Hanford Facility area of the Yakima region, high concentrations are largely the result of manmade changes in the ground-water chemistry (Lindberg and Bond, 1979).

Analyses of water from only four wells in Washington show dissolved-solids concentrations that exceed 10,000 mg/L. Three of these wells, two in Lewis County and one in Whatcom County, pump from marine-sedimentary deposits thought to contain water of connate origin. The fourth well, in King County, discharges at land surface a mixture of brine and natural gas that apparently comes from a small natural-gas reservoir.

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