Ground Water Classification Approaches: Importance and Applications

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Review…

- *What* is ground water (aquifer) classification?
- *Why* is it done?
- *Who* does it?
- *How* is it done?
- Considerations for the future.

Ground Water ‘Classification’….*What* is it?

Clas-si-fy *v.* To arrange or organize according to class or category. (The American Heritage Dictionary)

Syn: evaluate, grade, rank, rate (Webster’s Thesaurus)

Why is it done?

To establish limits in order to protect part, or all of aquifers according to their ‘class’ (i.e. grade, rank, or value). *Examples:*

- Ground water discharge and injection well permit limits for waste disposal (and GS)
- Ground water cleanup levels

‘Classification’: *How* is it done?

Two Common Approaches/Systems:

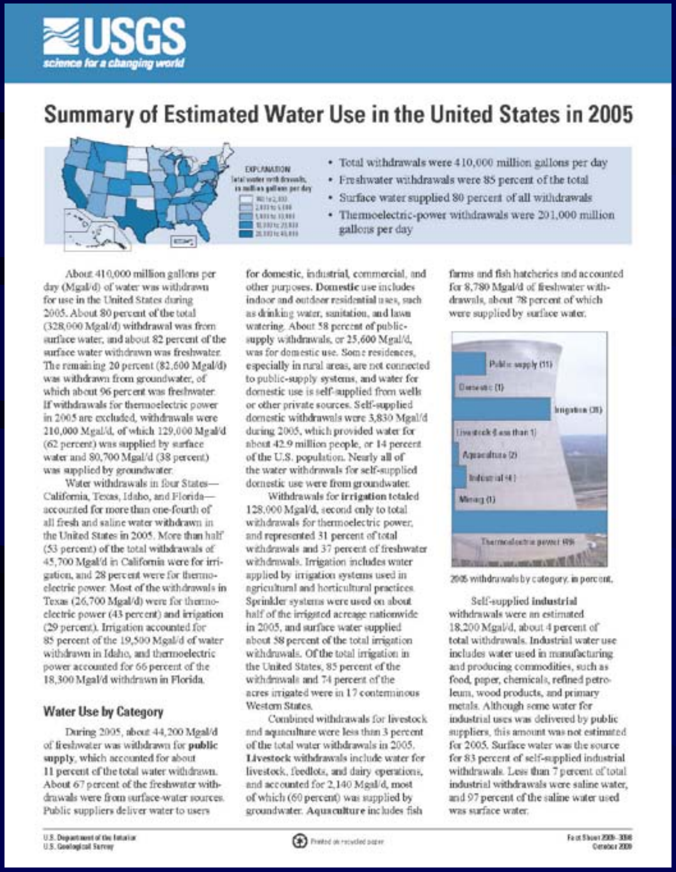
Classify aquifers (ground water) according to…

1. Type of ‘Use’, or
2. ‘Suitability’ for a specific type of use

Most states use one, or both systems

Types (Classes) of Ground water 'Use'

(Source: Estimated Use of Water in the United States in 20055, Kenny et al, USGS, Circ. 1344)



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Summary of Estimated Water Use in the United States in 2005

- Total withdrawals were 410,000 million gallons per day
- Freshwater withdrawals were 85 percent of the total
- Surface water supplied 80 percent of all withdrawals
- Thermoelectric-power withdrawals were 201,000 million gallons per day

About 410,000 million gallons per day (Mgal/d) of water was withdrawn for use in the United States during 2005. About 80 percent of the total (328,000 Mgal/d) withdrawal was from surface water, and about 82 percent of the surface water withdrawn was freshwater. The remaining 20 percent (82,600 Mgal/d) was withdrawn from groundwater, of which about 96 percent was freshwater. If withdrawals for thermoelectric power in 2005 are excluded, withdrawals were 210,000 Mgal/d, of which 129,000 Mgal/d (62 percent) was supplied by surface water and 80,700 Mgal/d (38 percent) was supplied by groundwater.

Water withdrawals in four States—California, Texas, Idaho, and Florida—accounted for more than one-fourth of all fresh and saline water withdrawn in the United States in 2005. More than half (53 percent) of the total withdrawals of 45,700 Mgal/d in California were for irrigation, and 28 percent were for thermoelectric power. Most of the withdrawals in Texas (26,700 Mgal/d) were for thermoelectric power (43 percent) and irrigation (29 percent). Irrigation accounted for 85 percent of the 19,500 Mgal/d of water withdrawn in Idaho, and thermoelectric power accounted for 66 percent of the 18,300 Mgal/d withdrawn in Florida.

Water Use by Category

During 2005, about 44,200 Mgal/d of freshwater was withdrawn for **public supply**, which accounted for about 11 percent of the total water withdrawn. About 67 percent of the freshwater withdrawals were from surface-water sources. Public suppliers deliver water to users for domestic, industrial, commercial, and other purposes. **Domestic** use includes indoor and outdoor residential uses, such as drinking water, sanitation, and lawn watering. About 58 percent of public-supply withdrawals, or 25,600 Mgal/d, was for domestic use. Some residences, especially in rural areas, are not connected to public-supply systems, and water for domestic use is self-supplied from wells or other private sources. Self-supplied domestic withdrawals were 3,830 Mgal/d during 2005, which provided water for about 42.9 million people, or 14 percent of the U.S. population. Nearly all of the water withdrawals for self-supplied domestic use were from groundwater.

Withdrawals for **irrigation** totaled 128,000 Mgal/d, second only to total withdrawals for thermoelectric power, and represented 31 percent of total withdrawals and 37 percent of freshwater withdrawals. Irrigation includes water applied by irrigation systems used in agricultural and horticultural practices. Sprinkler systems were used on about half of the irrigated acreage nationwide in 2005, and surface water supplied about 58 percent of the total irrigation withdrawals. Of the total irrigation in the United States, 85 percent of the withdrawals and 74 percent of the acres irrigated were in 17 conterminous Western States.

Combined withdrawals for livestock and aquaculture were less than 3 percent of the total water withdrawals in 2005. **Livestock** withdrawals include water for livestock, feedlots, and dairy operations, and accounted for 2,140 Mgal/d, most of which (60 percent) was supplied by groundwater. **Aquaculture** includes fish farms and fish hatcheries and accounted for 8,780 Mgal/d of freshwater withdrawals, about 78 percent of which were supplied by surface water.

Public supply (11)
Domestic (1)
Irrigation (31)
Livestock (less than 1)
Aquaculture (2)
Industrial (4)
Mining (1)
Thermoelectric power (49)

2005 withdrawals by category, in percent.

Self-supplied **industrial** withdrawals were an estimated 18,200 Mgal/d, about 4 percent of total withdrawals. Industrial water use includes water used in manufacturing and producing commodities, such as food, paper, chemicals, refined petroleum, wood products, and primary metals. Although some water for industrial uses was delivered by public suppliers, this amount was not estimated for 2005. Surface water was the source for 83 percent of self-supplied industrial withdrawals. Less than 7 percent of total industrial withdrawals were saline water, and 97 percent of the saline water used was surface water.

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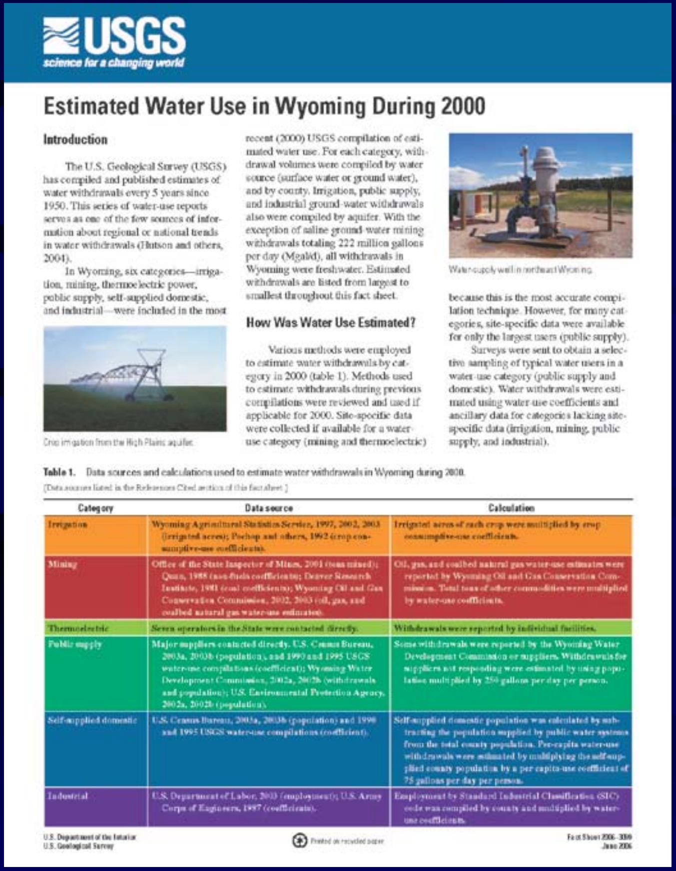
Fact Sheet 2009–3098
October 2009

- Domestic
- Irrigation
- Livestock
- Industry
- Mining
- (Aquaculture)
- (Thermoelectric)

* *Un-useable/unsuitable (tech/economical impractical)*

Classification by 'Use'

(Source: Estimated Water Use in Wyoming in 2000, Boughton et al, USGS, Fact Sheet 2006-3099)



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Estimated Water Use in Wyoming During 2000

Introduction

The U.S. Geological Survey (USGS) has compiled and published estimates of water withdrawals every 5 years since 1950. This series of water-use reports serves as one of the few sources of information about regional or national trends in water withdrawals (Hutson and others, 2004).

In Wyoming, six categories—irrigation, mining, thermoelectric power, public supply, self-supplied domestic, and industrial—were included in the most recent (2000) USGS compilation of estimated water use. For each category, withdrawal volumes were compiled by water source (surface water or ground water), and by county. Irrigation, public supply, and industrial ground-water withdrawals also were compiled by aquifer. With the exception of saline ground-water mining withdrawals totaling 22.2 million gallons per day (Mgal/d), all withdrawals in Wyoming were freshwater. Estimated withdrawals are listed from largest to smallest throughout this fact sheet.

Crop irrigation from the High Plains aquifer.

Water-supply well in northeast Wyoming.

How Was Water Use Estimated?

Various methods were employed to estimate water withdrawals by category in 2000 (table 1). Methods used to estimate withdrawals during previous compilations were reviewed and used if applicable for 2000. Site-specific data were collected if available for a water-use category (mining and thermoelectric) because this is the most accurate compilation technique. However, for many categories, site-specific data were available for only the largest users (public supply).

Surveys were sent to obtain a selective sampling of typical water users in a water-use category (public supply and domestic). Water withdrawals were estimated using water-use coefficients and ancillary data for categories lacking site-specific data (irrigation, mining, public supply, and industrial).

Table 1. Data sources and calculations used to estimate water withdrawals in Wyoming during 2000.

[Data sources listed in the References Cited section of this fact sheet.]

Category	Data source	Calculation
Irrigation	Wyoming Agricultural Statistics Service, 1997, 2002, 2003 (irrigated acres); Pochop and others, 1992 (crop consumptive-use coefficients).	Irrigated acres of each crop were multiplied by crop consumptive-use coefficients.
Mining	Office of the State Inspector of Mines, 2001 (tons mined); Quan, 1988 (non-fuels coefficients); Denver Research Institute, 1981 (coal coefficients); Wyoming Oil and Gas Conservation Commission, 2002, 2003 (oil, gas, and coalbed natural gas water-use estimates).	Oil, gas, and coalbed natural gas water-use estimates were reported by Wyoming Oil and Gas Conservation Commission. Total tons of other commodities were multiplied by water-use coefficients.
Thermoelectric	Seven operators in the State were contacted directly.	Withdrawals were reported by individual facilities.
Public supply	Major suppliers contacted directly. U.S. Census Bureau, 2003a, 2003b (population), and 1990 and 1995 USGS water-use compilations (coefficient); Wyoming Water Development Commission, 2002a, 2002b (withdrawals and population); U.S. Environmental Protection Agency, 2002a, 2002b (population).	Some withdrawals were reported by the Wyoming Water Development Commission or suppliers. Withdrawals for suppliers not responding were estimated by using population multiplied by 250 gallons per day per person.
Self-supplied domestic	U.S. Census Bureau, 2003a, 2003b (population) and 1990 and 1995 USGS water-use compilations (coefficient).	Self-supplied domestic population was calculated by subtracting the population supplied by public water systems from the total county population. Per-capita water-use withdrawals were estimated by multiplying the self-supplied county population by a per capita-use coefficient of 75 gallons per day per person.
Industrial	U.S. Department of Labor, 2003 (employment); U.S. Army Corps of Engineers, 1997 (coefficients).	Employment by Standard Industrial Classification (SIC) code was compiled by county and multiplied by water-use coefficients.

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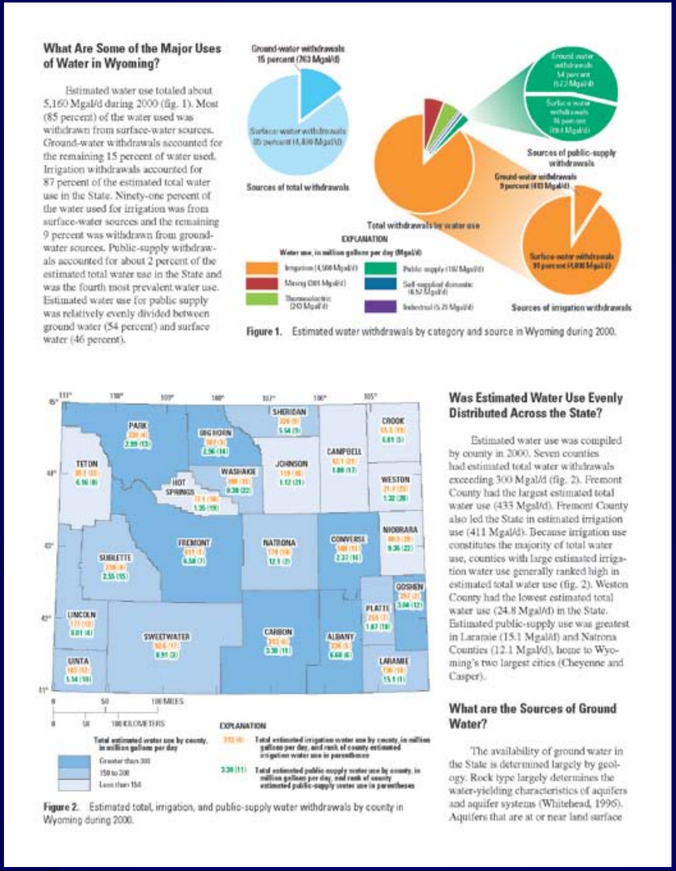
Fact Sheet 2006-3099
June 2006



What Are Some of the Major Uses of Water in Wyoming?

Estimated water use totaled about 5,160 Mgal/d during 2000 (fig. 1). Most (85 percent) of the water used was withdrawn from surface-water sources. Ground-water withdrawals accounted for the remaining 15 percent of water used. Irrigation withdrawals accounted for 87 percent of the estimated total water use in the State. Ninety-one percent of the water used for irrigation was from surface-water sources and the remaining 9 percent was withdrawn from ground-water sources. Public-supply withdrawals accounted for about 2 percent of the estimated total water use in the State and was the fourth most prevalent water use. Estimated water use for public supply was relatively evenly divided between ground water (54 percent) and surface water (46 percent).

Figure 1. Estimated water withdrawals by category and source in Wyoming during 2000.

Figure 2. Estimated total, irrigation, and public-supply water withdrawals by county in Wyoming during 2000.

Was Estimated Water Use Evenly Distributed Across the State?

Estimated water use was compiled by county in 2000. Seven counties had estimated total water withdrawals exceeding 300 Mgal/d (fig. 2). Fremont County had the largest estimated total water use (433 Mgal/d). Fremont County also led the State in estimated irrigation use (411 Mgal/d). Because irrigation use constitutes the majority of total water use, counties with large estimated irrigation water use generally ranked high in estimated total water use (fig. 2). Weston County had the lowest estimated total water use (24.8 Mgal/d) in the State. Estimated public-supply use was greatest in Laramie (15.1 Mgal/d) and Natrona Counties (12.1 Mgal/d), home to Wyoming's two largest cities (Cheyenne and Casper).

What are the Sources of Ground Water?

The availability of ground water in the State is determined largely by geology. Rock type largely determines the water-yielding characteristics of aquifers and aquifer systems (Whitehead, 1996). Aquifers that are at or near land surface

‘USDWs’: Classification by ‘Use’

“USDW”: An aquifer or part of an aquifer which…

• supplies any public water system, or

• contains a sufficient quantity of ground water to supply a public water system and currently supplies drinking water for human consumption (i.e. ‘Use’)

(and is not an exempted aquifer).

Who makes Classification by 'Use' determinations?

State agencies:

- Type of 'Use' (ground water rights)

EPA and/or states (SDWA/UIC):

- Type of 'Use' (Definition of USDW)

How is classification by 'Use' done?

Through a <u>permit to appropriate</u>, or use ground water (State Agencies).

- Usually for a <u>*specific type*</u> of use (e.g. domestic, irrigation. livestock, industry)
- For UIC permitting:
  - State permits (to appropriate) for 'domestic' use establish whether an aquifer is a USDW by 'Use'

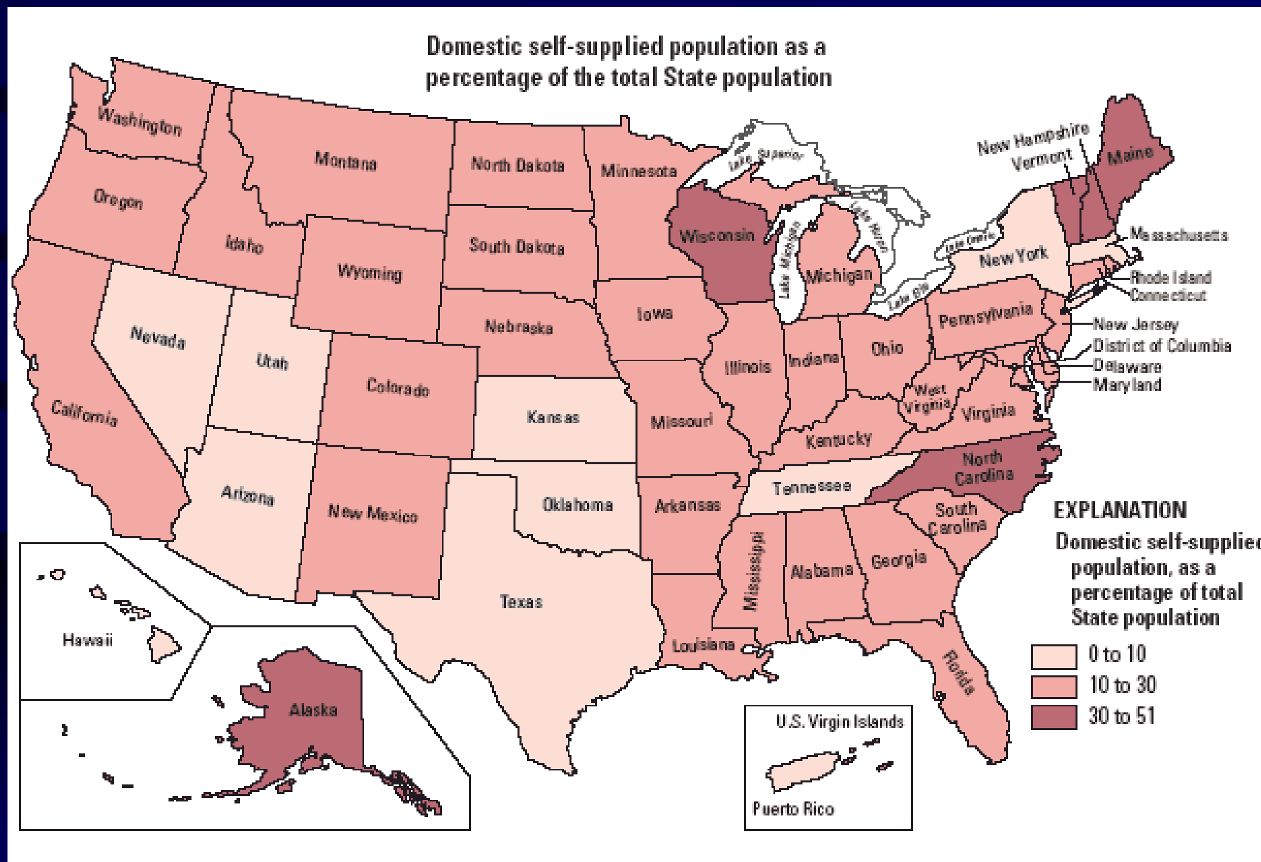
When Classification by 'Use' is, and is not appropriate

Usually an appropriate classification system where aquifers are being used, but is not useful for classifying aquifers that are not being used……

- Deep aquifers (most domestic, livestock, irrigation, industrial wells completed within shallower aquifers)
- Portions of shallow aquifers not being used (sparsely populated areas)

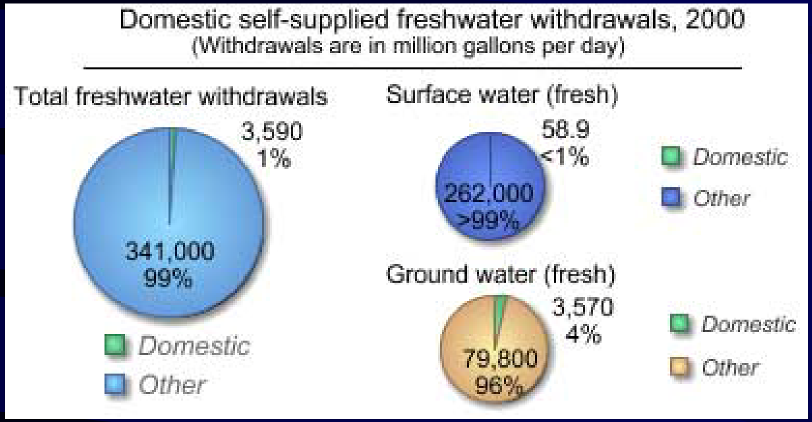
Classification by 'Use' Ambiguity

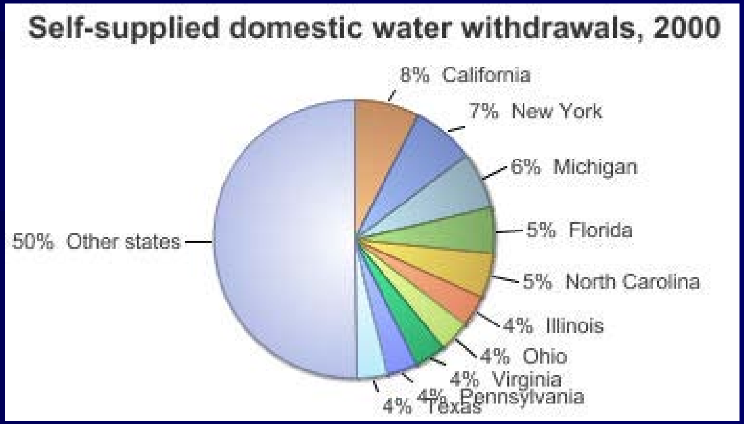
(Source: Estimated Use of Water in the United States in 2000, USGS, Cir. 1268)



Classification by 'Use': Public and Self-supplied drinking water

(Source: Estimated Use of Water in the United States in 2000, USGS, Cir. 1268)





Classification by ‘Use’ Ambiguity

Classification by type of ‘Use’, fails to consider whether the resource is <u>*suitable*</u> for that use, or not. For instance:

- Aquifers used for many self-supplied domestic use water supplies don’t meet ‘safe’ drinking water standards (e.g. arsenic > 10 ppb; sulfates > 250 mg/L; uranium > 30 ppb, but may be suitable for other types of uses (e.g. livestock, industry).
- POU treatment often required…..

2nd Approach: Classification by 'Suitability'

Classify aquifers by intrinsic, or *ambient chemical quality* , recognizing that variations in quality can determine the suitability of groundwater for one particular type of use, or another (e.g. domestic, irrigation, livestock, industry (or un-useable/unsuitable)

‘Use/Suitability’ Hierarchy

Domestic

Irrigation

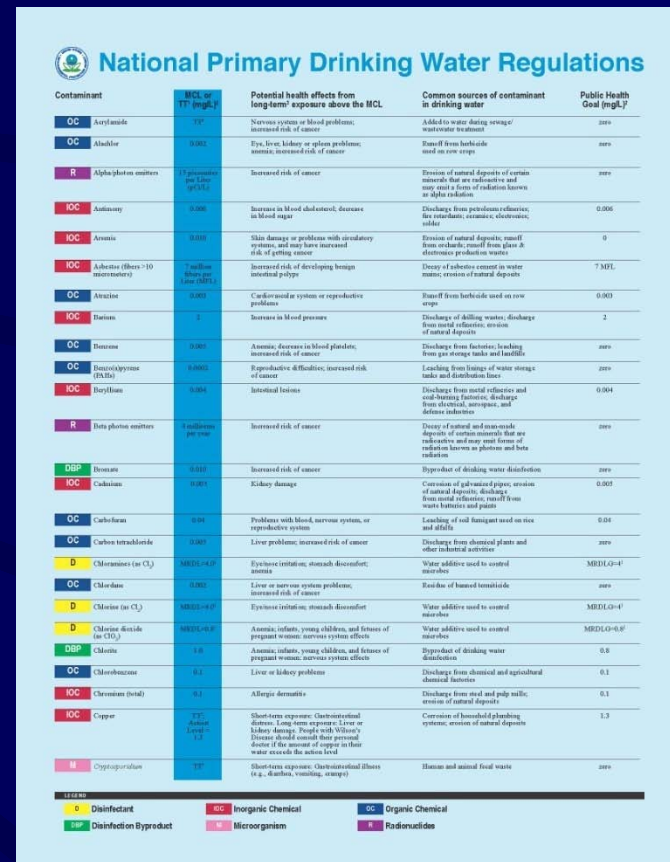
Livestock

Industry

Mineral and O & G

Un-useable/Unsuitable

Classification by 'Suitability': Domestic Use (Source: US EPA)



National Primary Drinking Water Regulations

Contaminant		MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
OC	Acrylamide	TT[8]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/ wastewater treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha/photon emitters	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards; runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort; anemia	Water additive used to control microbes	MRDLG=4[1]
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants, young children, and fetuses of pregnant women: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants, young children, and fetuses of pregnant women: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short-term exposure: Gastrointestinal distress. Long-term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero

LEGEND

D Disinfectant
DBP Disinfection Byproduct
IOC Inorganic Chemical
M Microorganism
OC Organic Chemical
R Radionuclides

Classification by ‘Suitability’:
Irrigation and Livestock Use

Classification by 'Suitability': Domestic, Irrigation, Livestock, Industrial

(Source: Wyoming Water Quality Rules and Regulations, Chapter 8)

TABLE I

UNDERGROUND WATER CLASS	I	II	III
Use Suitability	Domestic*	Agriculture	Livestock
Constituent or Parameter	Concentration**	Concent.**	Concent.**
Aluminum (Al)	---	5.0	5.0
Ammonia (NH_3-N)	0.5[7]	---	---
Arsenic (AS)	0.05	0.1	0.2
Barium (Ba)	2.0	---	---
Beryllium (Be)	---	0.1	---
Boron (B)	0.75	0.75	5.0
Cadmium (Cd)	.005	0.01	0.05
Chloride (Cl)	250.0	100.0	2000.0
Chromium (Cr)	.10	0.1	0.05
Cobalt (Co)	---	0.05	1.0
Copper (Cu)	1.0	0.2	0.5
Cyanide (CN)	0.2	---	---
Fluoride (F)	4.0	---	---
Hydrogen Sulfide (H_2S)	0.05	---	---
Iron (Fe)	0.3	5.0	---
Lead (Pb)	.015	5.0	0.1
Lithium (Li)	---	2.5	---
Manganese (Mn)	0.05	0.2	---
Mercury (Hg)	0.002	---	0.00005
Nickel (Ni)	---	0.2	---
Nitrate (NO_3-N)	10.0	---	---
Nitrite (NO_2-N)	1.0	---	10.0
(NO_3+NO_2)-N	---	---	100.0
Oil & Grease	Virtually Free	10.0	10.0
Phenol	0.001	---	---
Selenium (Se)	.05	0.02	0.05
Silver (Ag)	.10	---	---
Sulfate (SO_4)	250.0	200.0	3000.0
Total Dissolved Solids (TDS)	500.0	2000.0	5000.0
Vanadium (V)	---	0.1	0.1
Zinc (Zn)	5.0	2.0	25.0
pH	6.5-8.5	4.5-9.0s.u.	6.5-8.5s.u
SAR	---	8	---
RSC	---	1.25 meq/L	---
CombinedTotal Radium 226 and Radium 228[8]	5pCi/L	5pCi/L	5pCi/L
Total Strontium 90	8pCi/L	8pCi/L	8pCi/L
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium[8]	15pCi/L	15pCi/L	15pCi/L

* This list does not include all constituents in the national drinking water standards.

** mg/L, unless other wise indicated

Classification by ‘Suitability’: Other Classes

- Un-suitable for use:
  - Excessively high TDS (saline aquifers)
  - Presence of contaminants at levels impractical to treat

USDW: Classification by ‘Suitability’

“USDW”: An aquifer or part of an aquifer which…

•contains <u>fewer than 10,000 mg/ L of TDS</u>

(and is not an exempted aquifer)

Who does it?

State agencies:

- ‘Suitability’ (‘baseline’ ground water quality)

EPA and/or states (SDWA/UIC):

- ‘Suitability’ (Definition of USDW)

When Classification by 'Suitability' is, and is not appropriate

Is an appropriate classification system where aquifers are not being used…(deep aquifers, portions of aquifers in sparsely populated areas)…but is not always appropriate where aquifers are being used (in order to protect highest beneficial use)

(Domestic > Irrigation > Livestock)

Considerations

States should *always* protect groundwater to the highest beneficial 'Use' it is being <u>used for</u>, regardless of it's 'Suitability'….

•*Many self-supplied ground water users depend upon 'un-suitable' ground water supplies for domestic use…*

Remember the Use/Suitability Hierarchy!

Considerations

More research is needed to understand and identify toxicity limits for chemical constituents in ground water used for irrigation, livestock, and industrial purposes.

The 'tordon' example….

Considerations

More research is needed to develop affordable, effective water treatment systems for those dependent upon self-supplied ground water supplies.

Considerations

- Any national ground water inventory should describe (classify) both aquifers that are, **<u>and</u>** are not being used in terms of their intrinsic ‘<u>suitability</u>’ for specific uses (domestic, irrigation, livestock, industrial, or as ‘unsuitable’ for use) in order to accurately assess future development potential, and cost to develop.

Thank you…

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