Decoding UCMR3: Clear Communication with the Public about Drinking Water Contaminants,

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U.S. Geological Survey

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10/25/2013

Naturally Occurring	Synthesized
Vanadium *	1,2,3-trichloropropane
Molybdenum	1,3-butadiene
Cobalt	Chloromethane
Strontium *	1,1-dichloroethane
Chromium *	Bromomethane
Chromium VI *	Chlorodifluoromethane
Chorate *	bromochloromethane
Estradiol	1,4-dioxane
Estriol	perfluorooctanesulfonic acid
Equilin	perfluorooctanoic acid
Estrone	perfluorononanoic acid
Testosterone	perfluorohexanesulfonic acid
Androstenedione	perfluoroheptanoic acid
Enterovirus	perfluorobutanesulfonic acid
Norovirus	Ethinyl estradiol

* Detected in initial sampling

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Appendix 9. Concentration statistics for trace elements analyzed in public-well samples collected during 1993–2007.

[µg/L, micrograms per liter. A percentile is the value below which a certain percentage of observations fall. For example, 90 percent of the samples had concentrations less than the 90th percentile. <, less than; < values correspond to the common assessment level for a given compound; ND, not detected]

Trace element	Common assessment level = 1 µg/L[1]								
	Number of samples	Number of detections	Detection frequency (percent)	Percentile concentrations (µg/L)					Maximum detected concentration
				10th	25th	50th (median)	75th	90th	
Aluminum	598	262	43.8	<1	<1	<1	2.7	5.8	412
Antimony	619	4	0.6	<1	<1	<1	<1	<1	9.5
Arsenic	638	280	43.9	<1	<1	<1	2.4	9.4	97.7
Barium	630	625	99.2	7.1	16.9	46.7	96.2	164.1	11,080
Beryllium	622	0	0	ND	ND	ND	ND	ND	ND
Boron	501	459	91.6	14.7	23.2	51.4	113.5	360.9	1,895
Cadmium	631	1	0.2	<1	<1	<1	<1	<1	2
Chromium	626	226	36.1	<1	<1	<1	1.8	4.3	34.4
Cobalt	627	15	2.4	<1	<1	<1	< 1	< 1	10.8
Copper	625	335	53.6	<1	<1	1.2	2.5	5.5	88.9
Iron	809	356	44.0	<10	<10	<10	100	714.2	17,000
Lead	630	107	17.0	<1	<1	<1	<1	1.8	46.5
Lithium	458	395	86.2	<1	2.0	4.8	18.6	78.9	650
Manganese	808	437	54.1	<1	<1	1.6	17	97.1	1,923
Molybdenum	628	332	52.9	<1	<1	1.1	3.4	6.7	89
Nickel	629	272	43.2	<1	<1	<1	1.9	4.1	25.6
Selenium	632	135	21.4	<1	<1	<1	<1	1.9	62.0
Silver	606	0	0	ND	ND	ND	ND	ND	ND
Strontium	503	503	100	84.3	204.5	384.5	754.9	1,811.3	43,950
Thallium	437	1	0.2	<1	<1	<1	<1	<1	1.7
Uranium	650	278	42.8	<1	<1	<1	2.8	6.9	86.8
Vanadium	457	285	62.4	<1	<1	2.5	8.1	21.9	121
Zinc	613	515	84.0	<1	1.5	3.7	8.0	22.4	3,290

[1] Common assessment level was 12 µg/L for boron and 10 µg/L for iron.

		Crustal abundance (rank)	Crustal abundance (mean PPM)	USGS Detection Frequency	USGS Max Concentration (ug/L)
	Cobalt	31	30	2	11
Major Industrial	Chromium	21	140	36	34
Major Industrial	Molybdenum	53	1.1	53	89
1	Strontium	15	360	100	43,950
2	Vanadium	19	190	62	121

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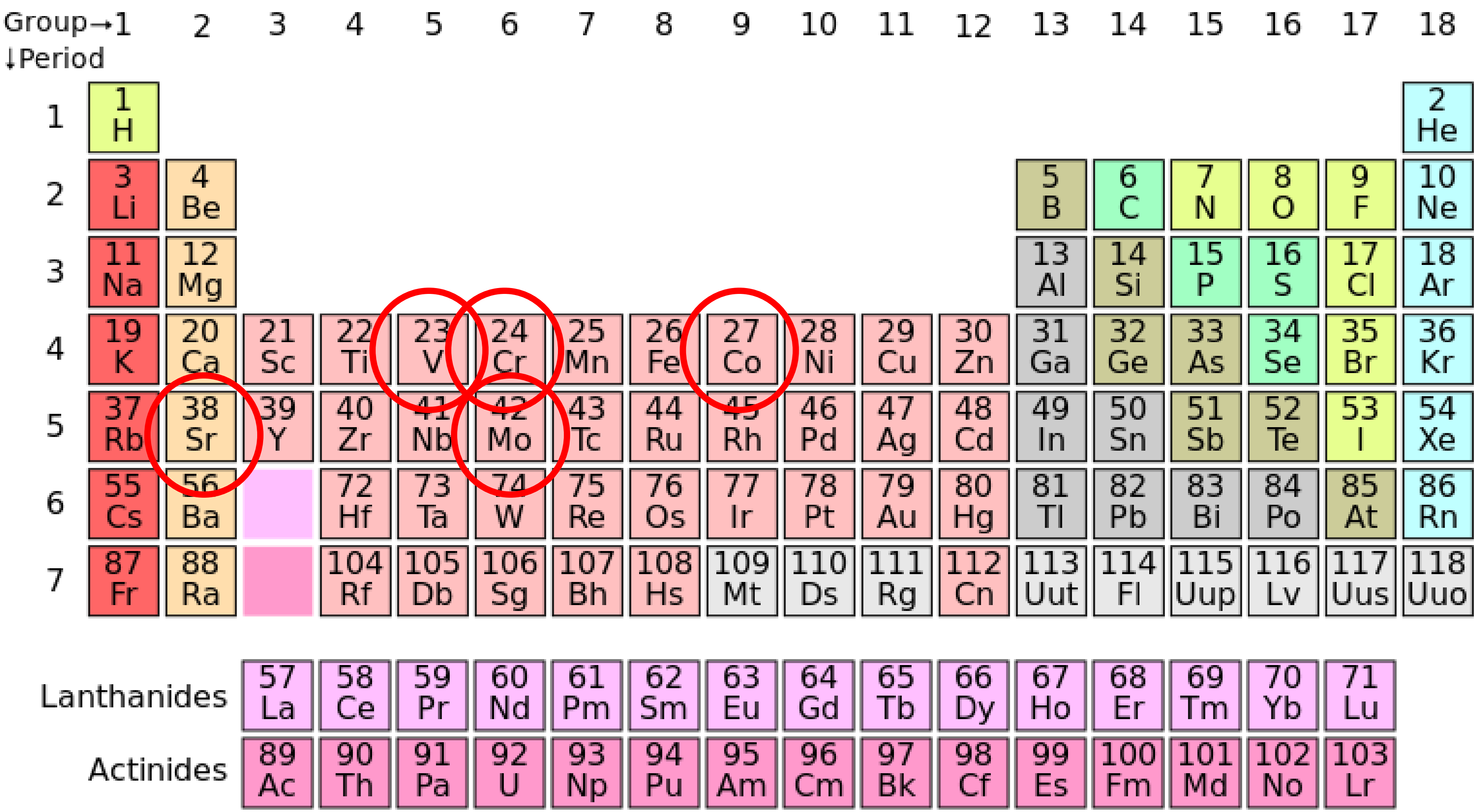
V, Cr, Co, Mo are transistion metals which exhibit two or more oxidation states in water.
Sr is an alkaline earth metal and therefore behaves similarly to calcium in water.



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Strontium (alkaline earth)

Strontium is the 15th most abundant element in Earth's crust and occurs naturally in many environmental compartments including rocks, soil, streambed sediment, water, and air.

Strontium has physical and chemical properties similar to those of its two neighbors calcium and barium.

Strontium compounds are often very soluble in water and therefore c can move through the environment fairly easily.

The mean strontium content of ocean water is 8 mg/l. Mean crustal concentration is 360 ppm.

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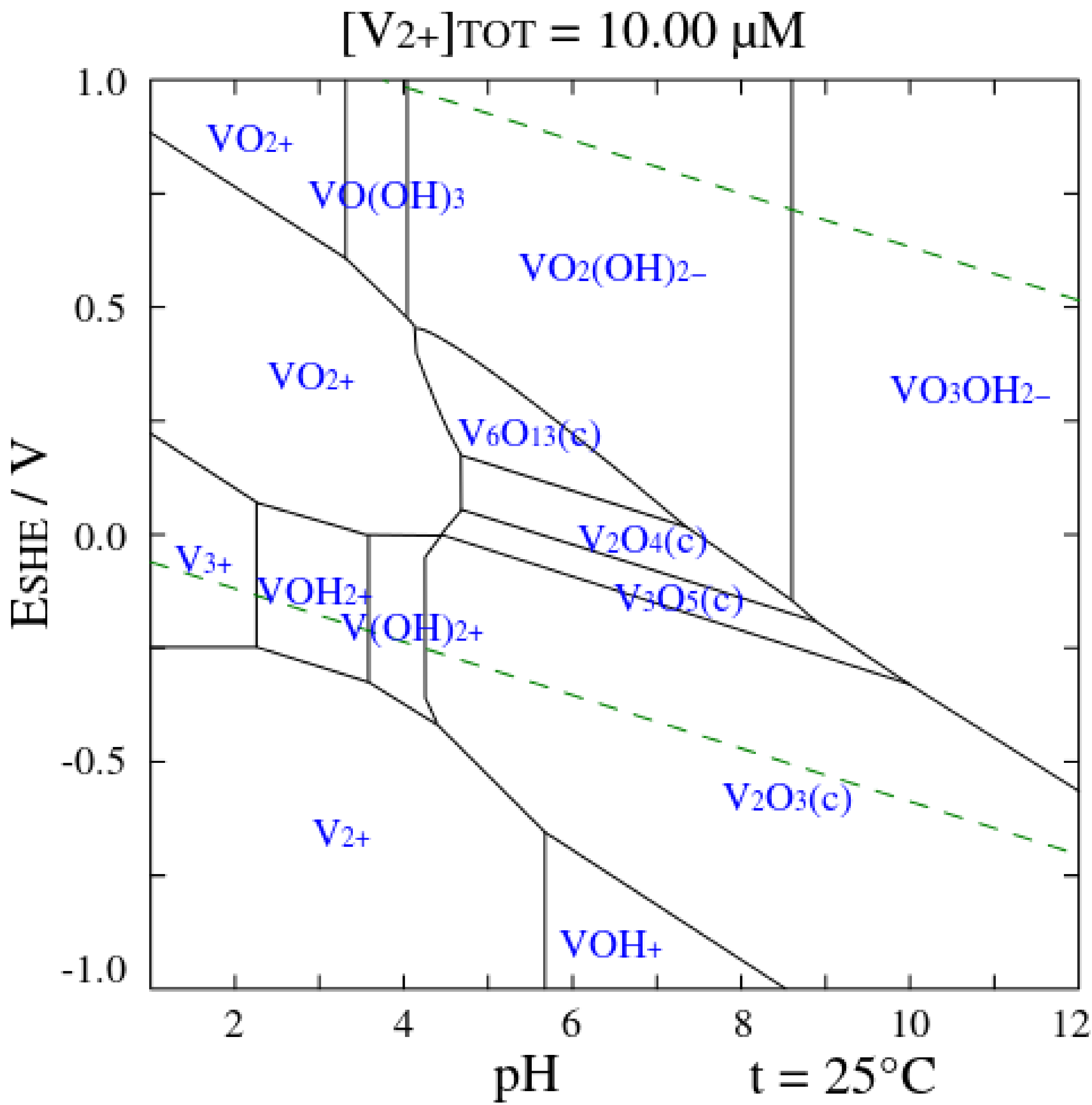
Vanadium (transition metal)

Vanadium is the 19th most abundant element in Earth's crust. Metallic vanadium is not found in nature, but is known to exist in about 65 different minerals.

The natural release of vanadium to water and soils occurs primarily as a result of weathering of rocks and soil erosion. This process usually involves the conversion of the less-soluble trivalent form to the more soluble pentavalent form.

In aqueous solution, vanadium(V) forms an extensive family of oxyanions. This is a pH-dependent redox process that controls environmental occurrence. Under reducing conditions it is generally in the V^{4+} ion form and under oxidizing it is in the V^{5+} form.

Mean crustal concentration is 190 ppm.



[V2+]TOT = 10.00 μM
1.0
0.5
0.0
-0.5
-1.0
ESHE / V
2
4
6
8
10
12
pH
t = 25°C
VO2+
VO(OH)3
VO2(OH)2–
VO2+
VO3OH2–
V6O13(c)
V2O4(c)
V3O5(c)
V3+
VOH2+
V(OH)2+
V2O3(c)
V2+
VOH+

Molybdenum

Molybdenum is the 53rd most abundant element in Earth's crust . Molybdenum does not occur naturally as a free metal on Earth, but rather in various oxidation states in minerals.

Most molybdenum compounds have low solubility in water. The molybdate ion MoO_4^{2-} is soluble and forms when molybdenum-containing minerals are in contact with oxygen and water

Mean crustal concentration is 1.1 ppm.

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Cobalt

Cobalt is the 31st most abundant element in Earth's crust and is found only in chemically combined form.

Common oxidation states of cobalt include +2 and +3, although compounds with oxidation states ranging from −3 to +4 are also known.

Cobalt in the environment is often strongly attached to soil or streambed particles. However, the form of the cobalt and the nature of the hydrogeologic environment at a particular site will affect how far cobalt will travel. Ultimately, most cobalt ends up in the soil or sediment.

Mean crustal concentration is 30 ppm.

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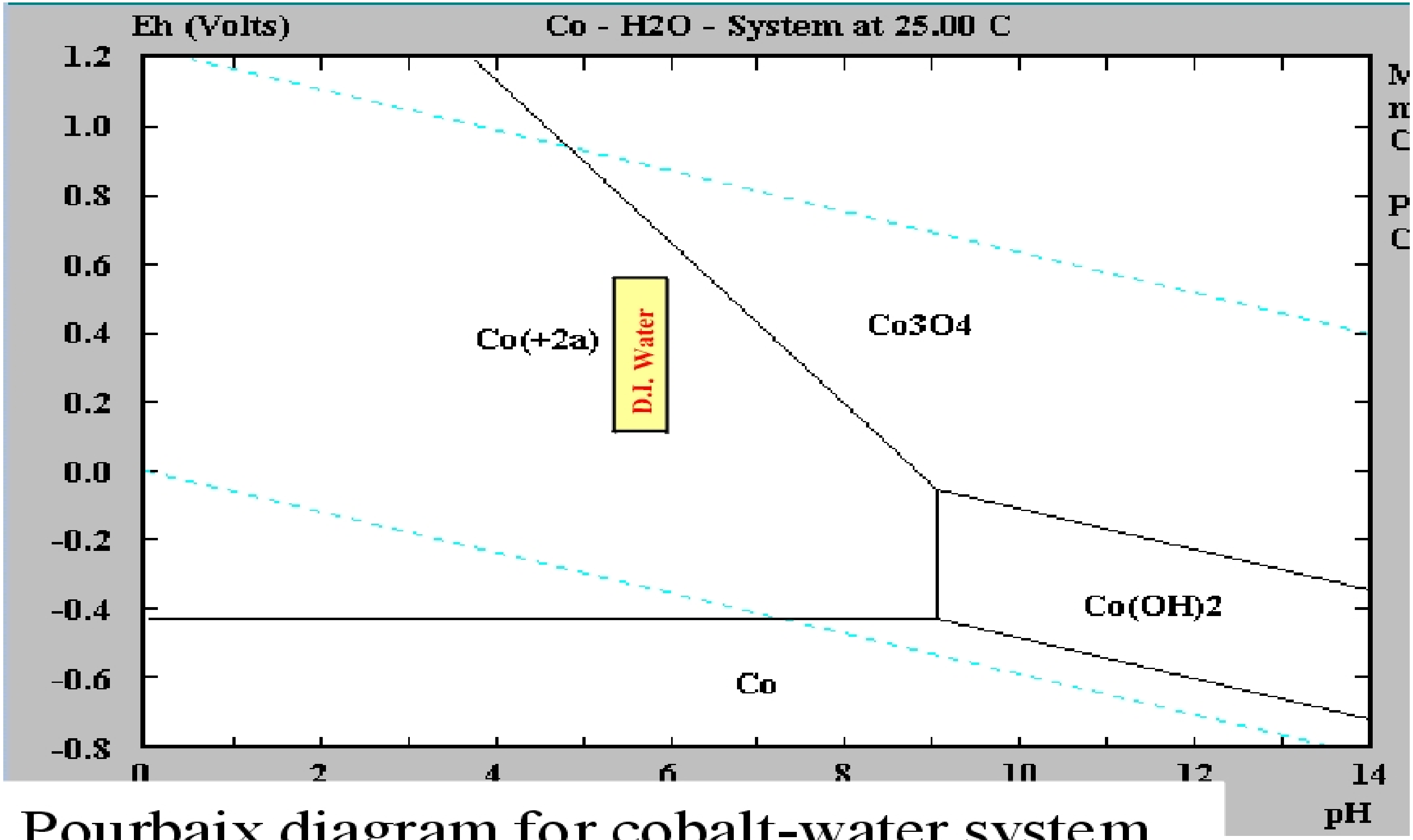

Pourbaix diagram for cobalt-water system

Chromium

Chromium is the 21st most abundant element in Earth's crust. Chromium compounds are found in the environment, due to erosion of chromium-containing rocks.

Chromium exists in oxidation states ranging from +6 to -2, however, only the +6 and +3 oxidation states are commonly encountered in the environment.

Cr(lll) is immobile under most common environmental conditions. Cr(Vl) is relatively mobile in the environment. Fate and transport of chromium in the environment is therefore dependent on the local geochemical and hydrogeological conditions.

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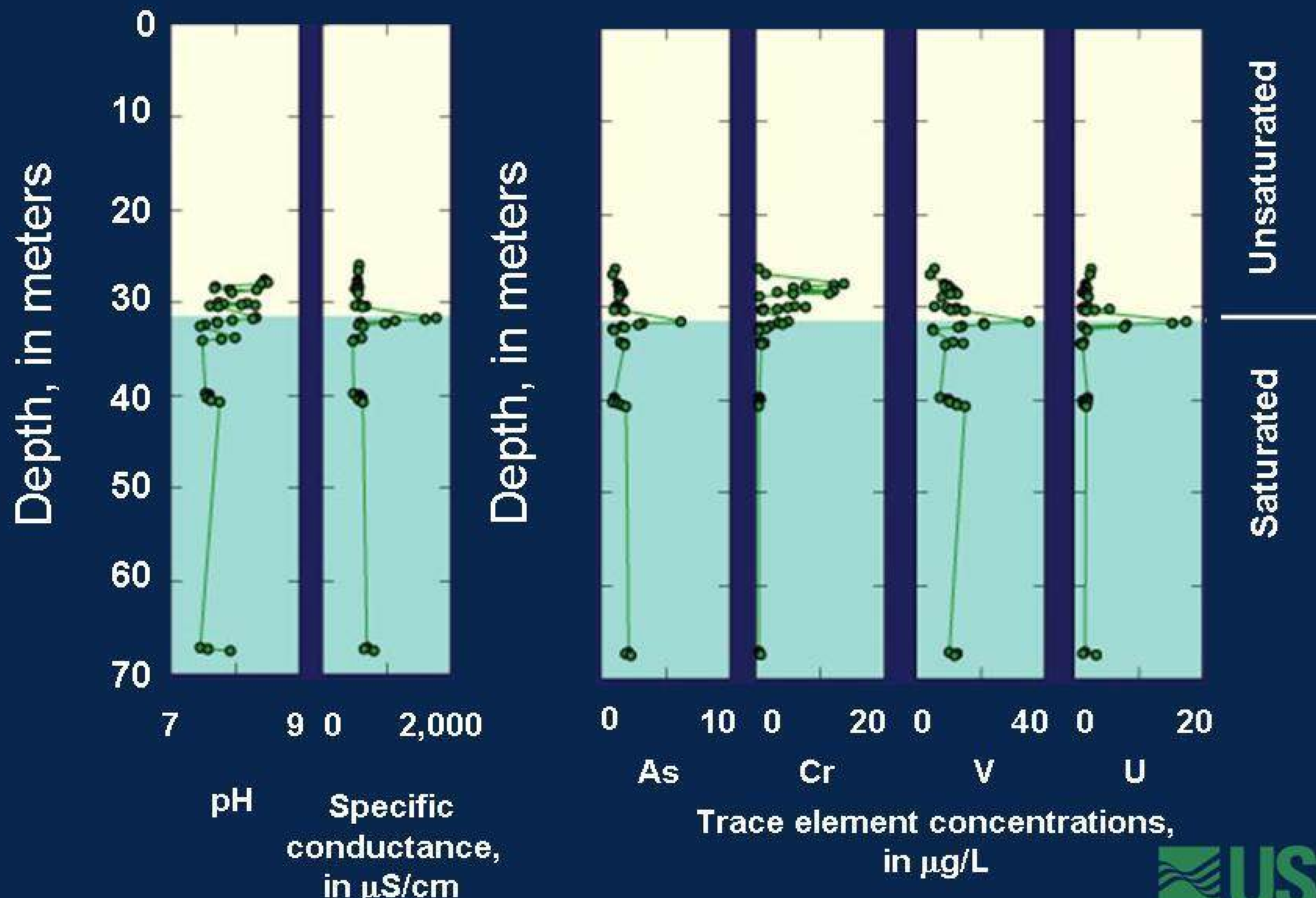
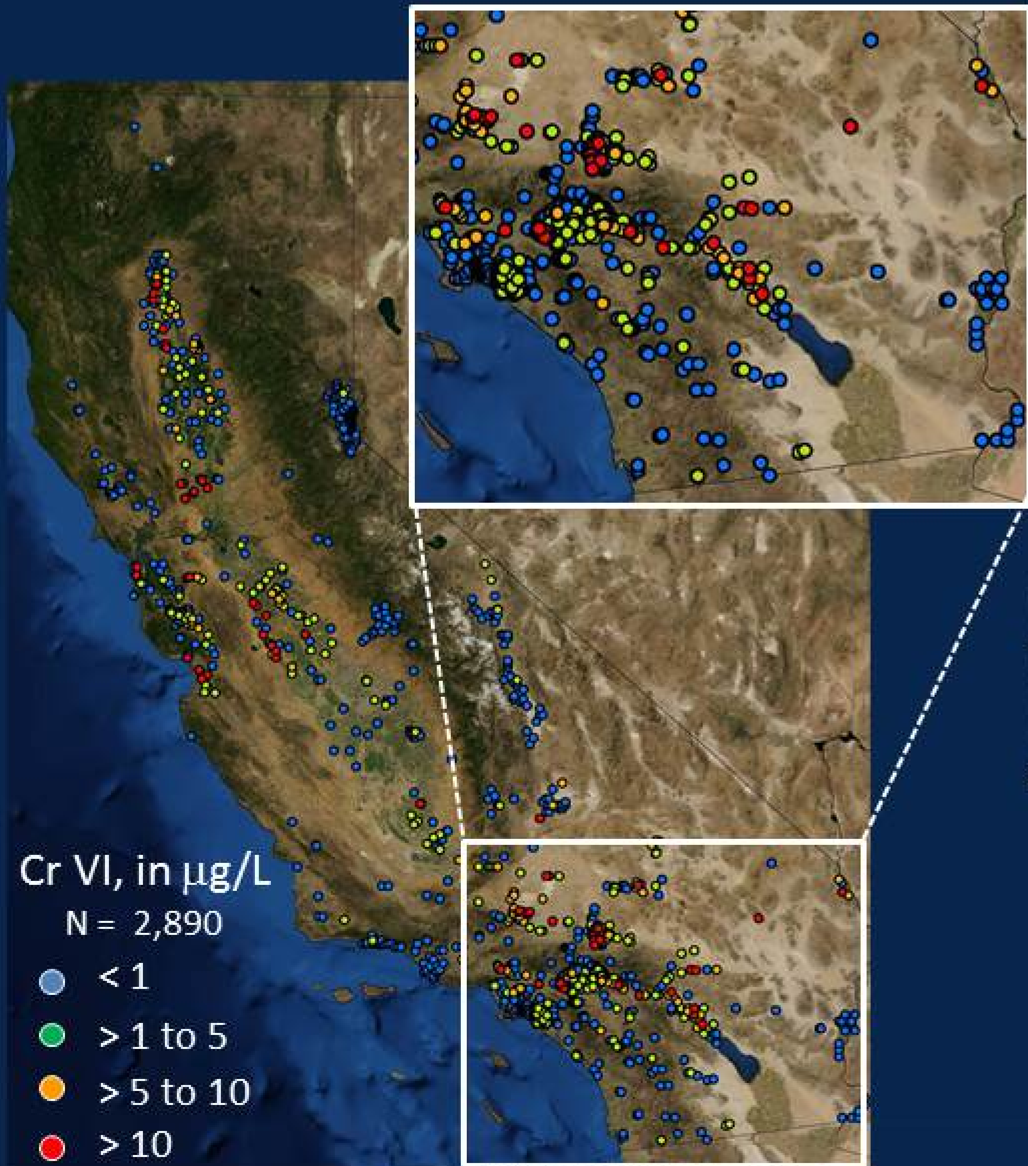
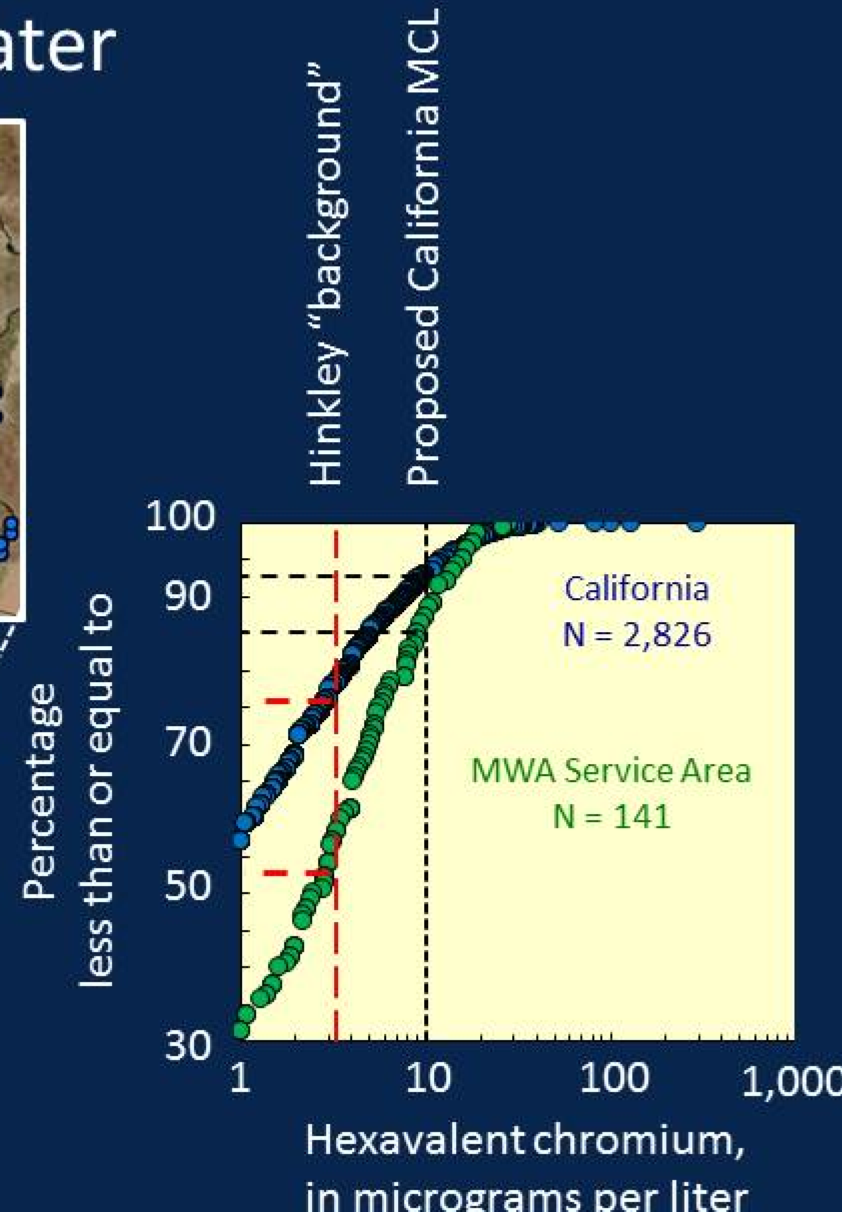
Trace element concentrations at the water table



Cr VI in California's groundwater





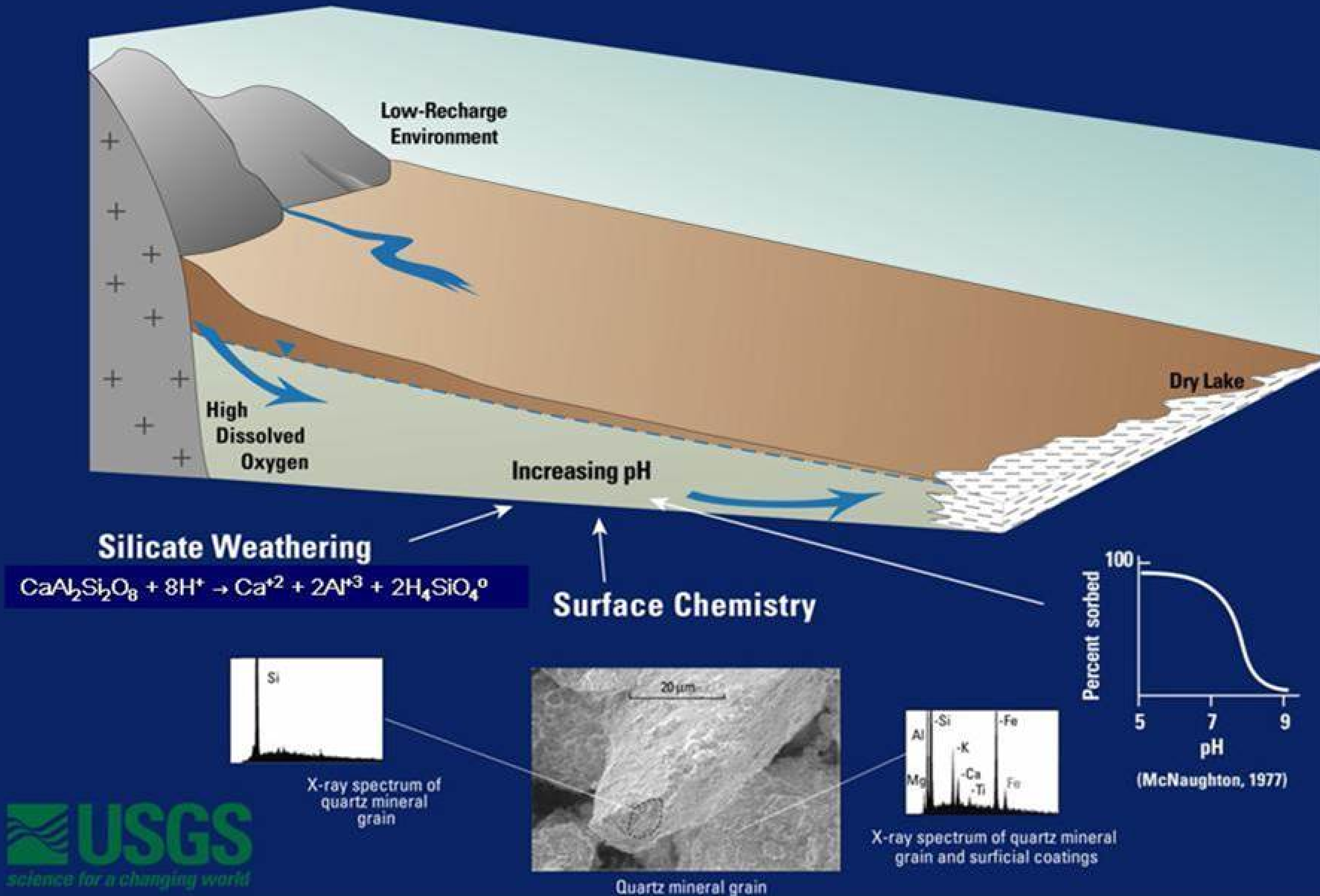
U.S. Geological Survey GAMA data

Can we discern natural vs anthropogenic sources?

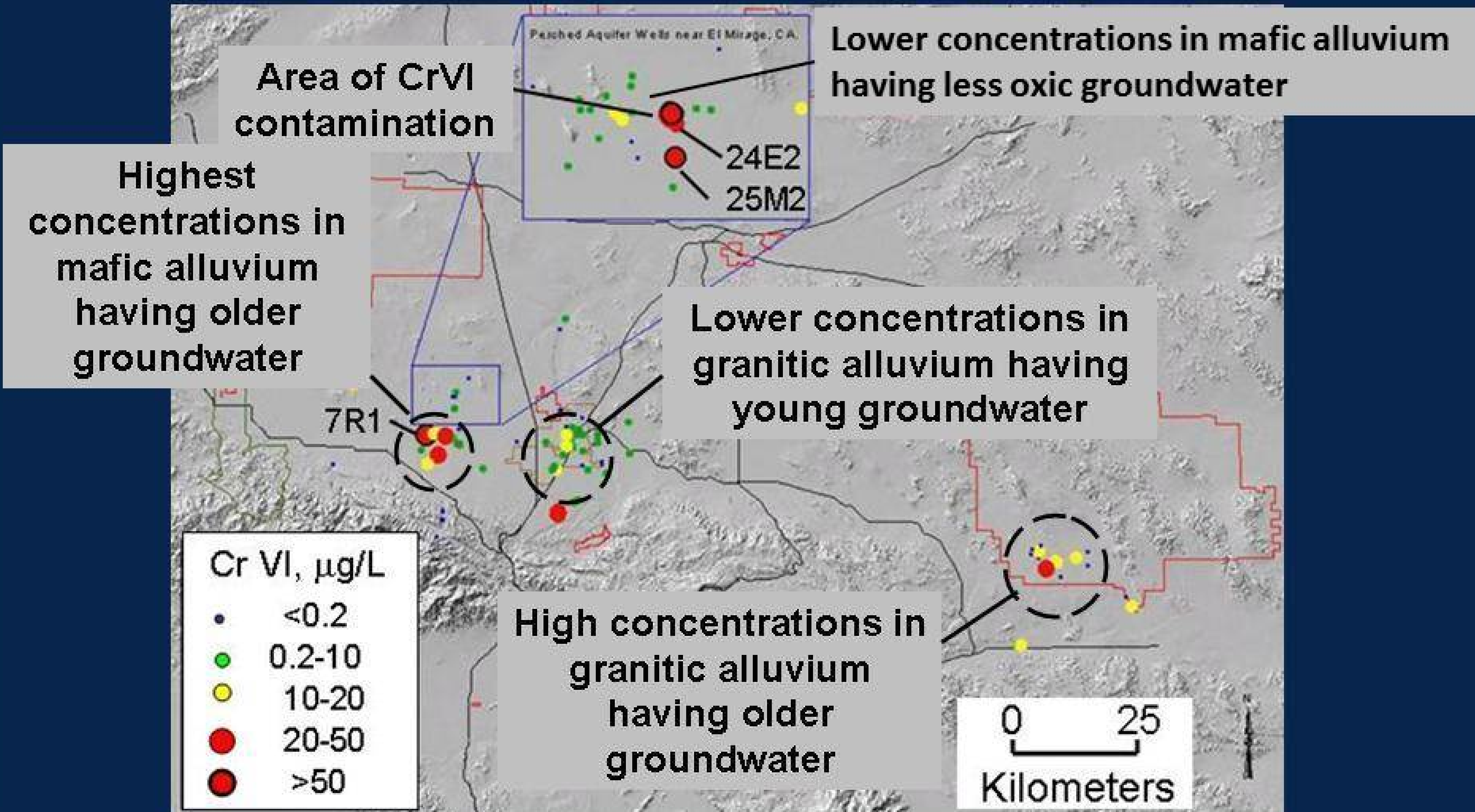
Well number	Date	pH (standard units)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Chromium		
					Cr (T) (µg/L)	Cr (VI) (µg/L)	Cr (III) (µg/L)
Native groundwater							
6N/7W-24D1	06/03/02	7.8	531	–	9.3	8.3	1.0
6N/7W-24E2	06/06/02	7.7	554	–	22.4	22.1	0.3
6N/7W-25M2	05/18/01	8.0	1520	6.1	–	55	–
6N/7W-25M2	*06/05/02*	*8.0*	*1520*	*6.1*	*59.6*	*60.5*	*<0.1*
6N/7W-26J2	06/05/02	8.3	702	1.2	3.9	2.7	1.2
6N/7W-27B8	01/23/03	8.6	513	12.2	8.9	8.6	0.3
6N/7W-29N2	06/03/02	7.5	513	<0.2	4.0	3.0	1.1
Contaminated groundwater							
EM-1	06/04/02	8.4	812	–	14.5	13.7	0.8
EM-3	06/03/02	8.4	562	–	21.0	20.2	0.8
EM-13	06/05/02	7.4	4850	7.3	330	310	20.0
EM-16	06/05/02	7.5	3350	2.9	34.8	30.8	4.0
EM-17	06/03/02	7.5	6070	6.5	34.5	30.9	3.6
EM-19	06/04/02	7.4	3440	5.5	130	107	23
EM-23	06/04/02	7.5	4920	–	31.2	28.8	2.4
EM-M2	06/05/02	7.7	2380	5.1	38.6	37.4	<0.1
EM-M4	06/05/02	7.1	5180	4.5	60.8	56.8	4.0
EM-P1	06/03/02	7.4	6180	4.9	44.5	44.0	0.5

Izbicki et al., (2012) Applied Geochemistry

Natural processing of redox-controlled inorganics along flowpaths



Chromium VI concentrations, Western Mojave Desert, Calif.



More than 200 samples collected and analyzed in 2001 and 2002

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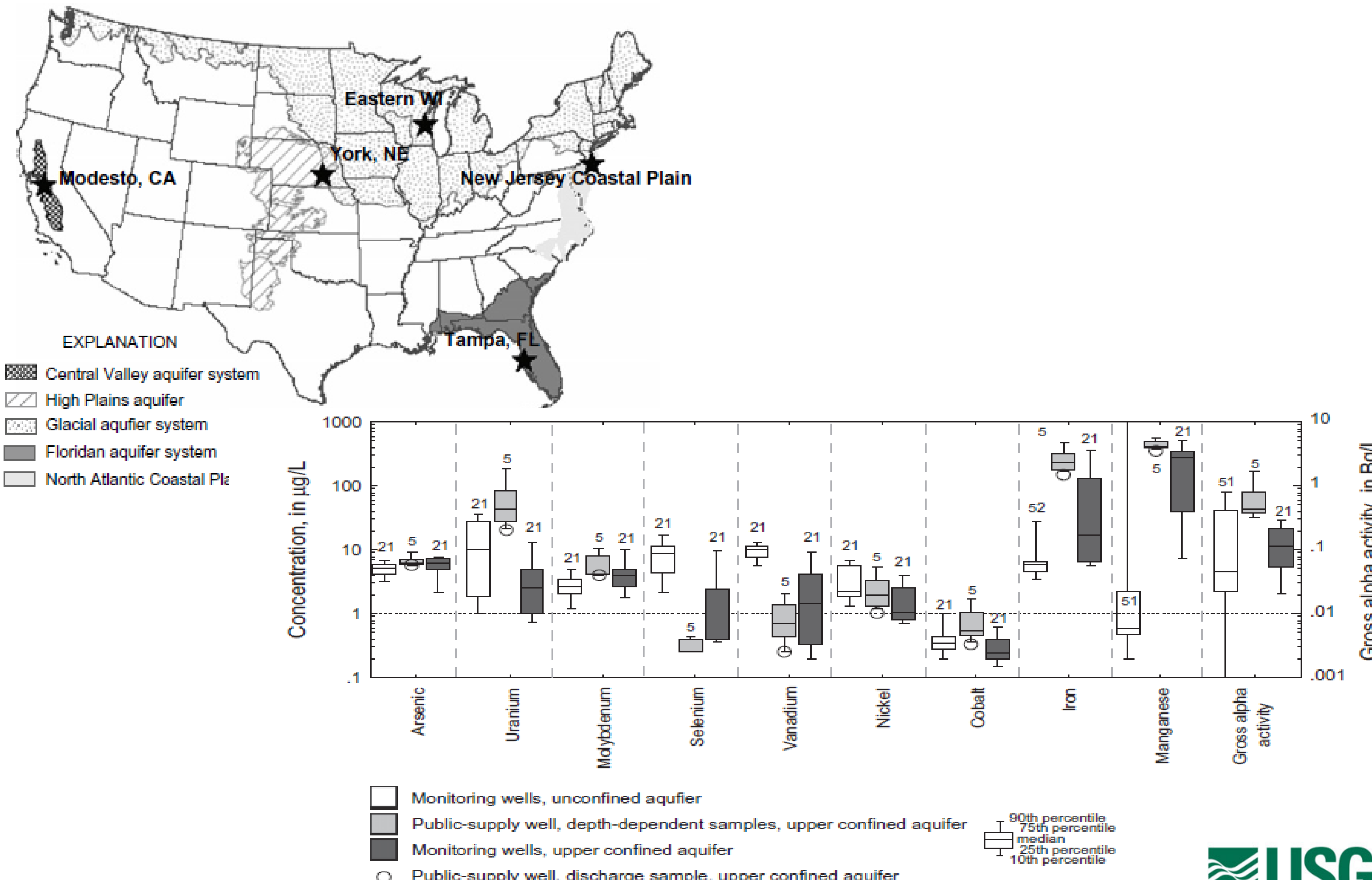
Can anthropogenic activities impact the fate and transport of inorganics in the environment?

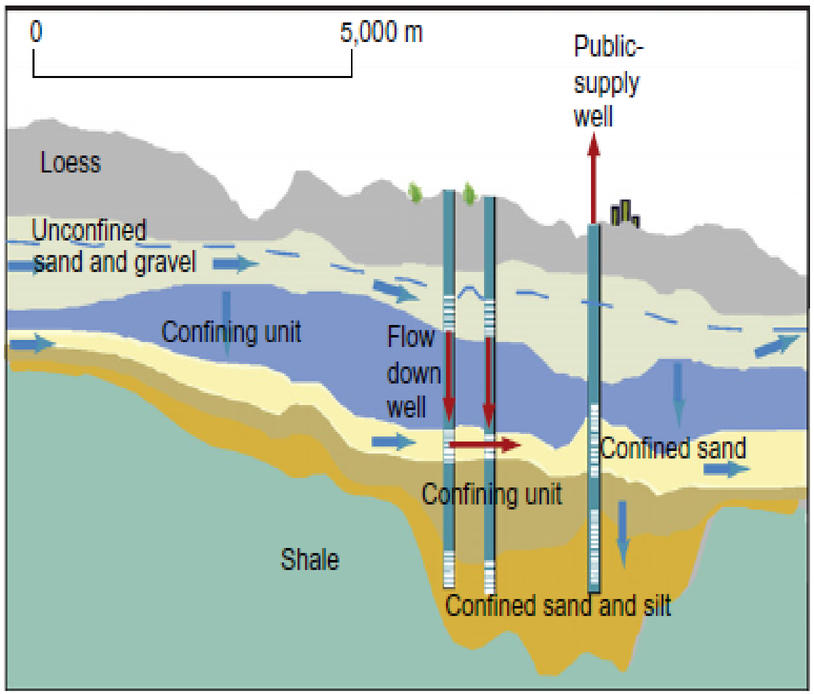


In the High Plains aquifer near York, Nebraska, mixing of shallow, oxygenated, lower-pH water from an unconfined aquifer with deeper, confined, anoxic, higher-pH water is facilitated by wells screened across both aquifers.

The resulting higher-O2, lower-pH mixed groundwater facilitated the mobilization of U from solid aquifer materials, and dissolved U concentrations were observed to increase significantly in nearby supply wells.

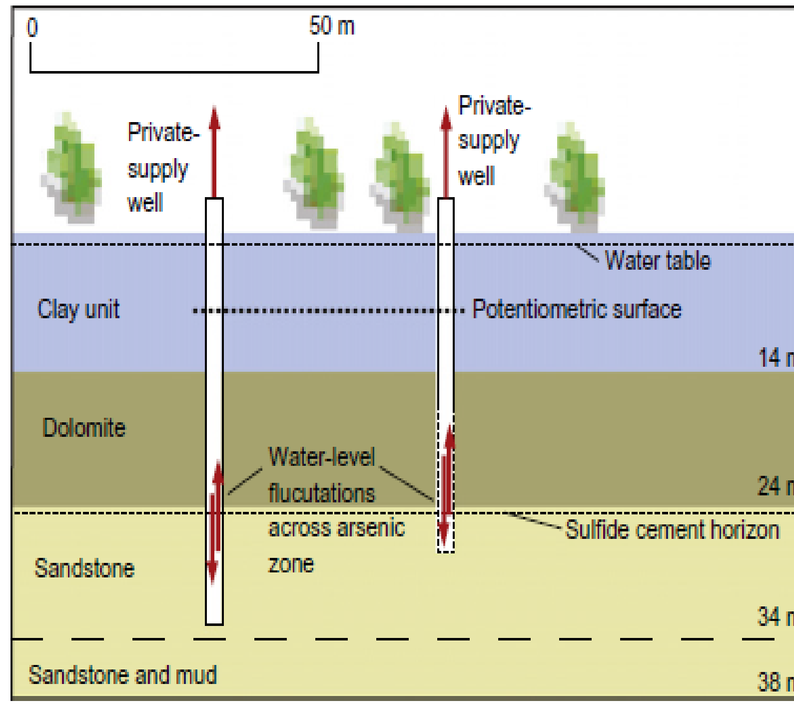
Similar mixing occurred in the Paleozoic sedimentary aquifers of eastern WI where high concentrations of As were mobilized.

(C) York, NE



Vertical scale exaggerated

(D) Eastern WI



Vertical scale exaggerated

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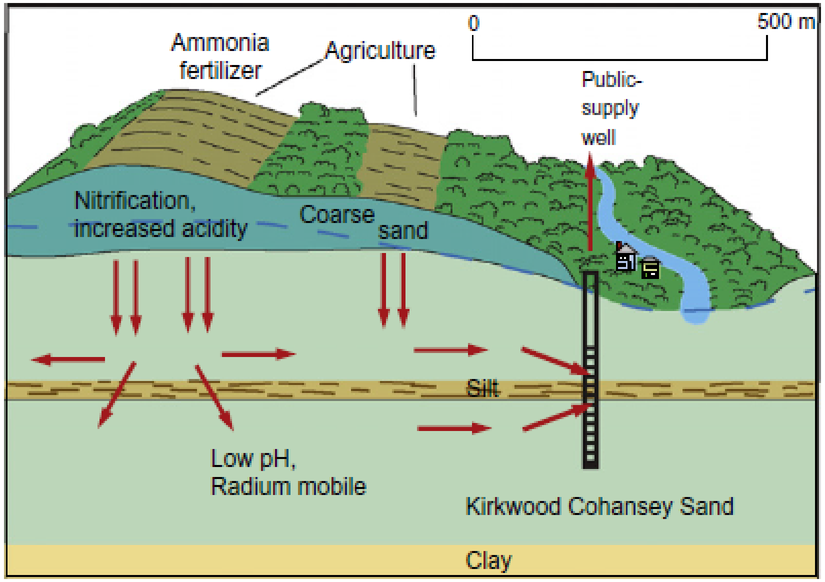
The results show that human activities including various land uses, well drilling, and pumping rates and volumes can adversely impact the quality of water in supply wells, when associated with naturally-occurring trace elements in aquifer materials. This occurs by causing subtle but significant changes in geochemistry and associated trace element mobilization as well as enhancing advective transport processes.

(F) New Jersey Coastal Plain



Vertical scale exaggerated

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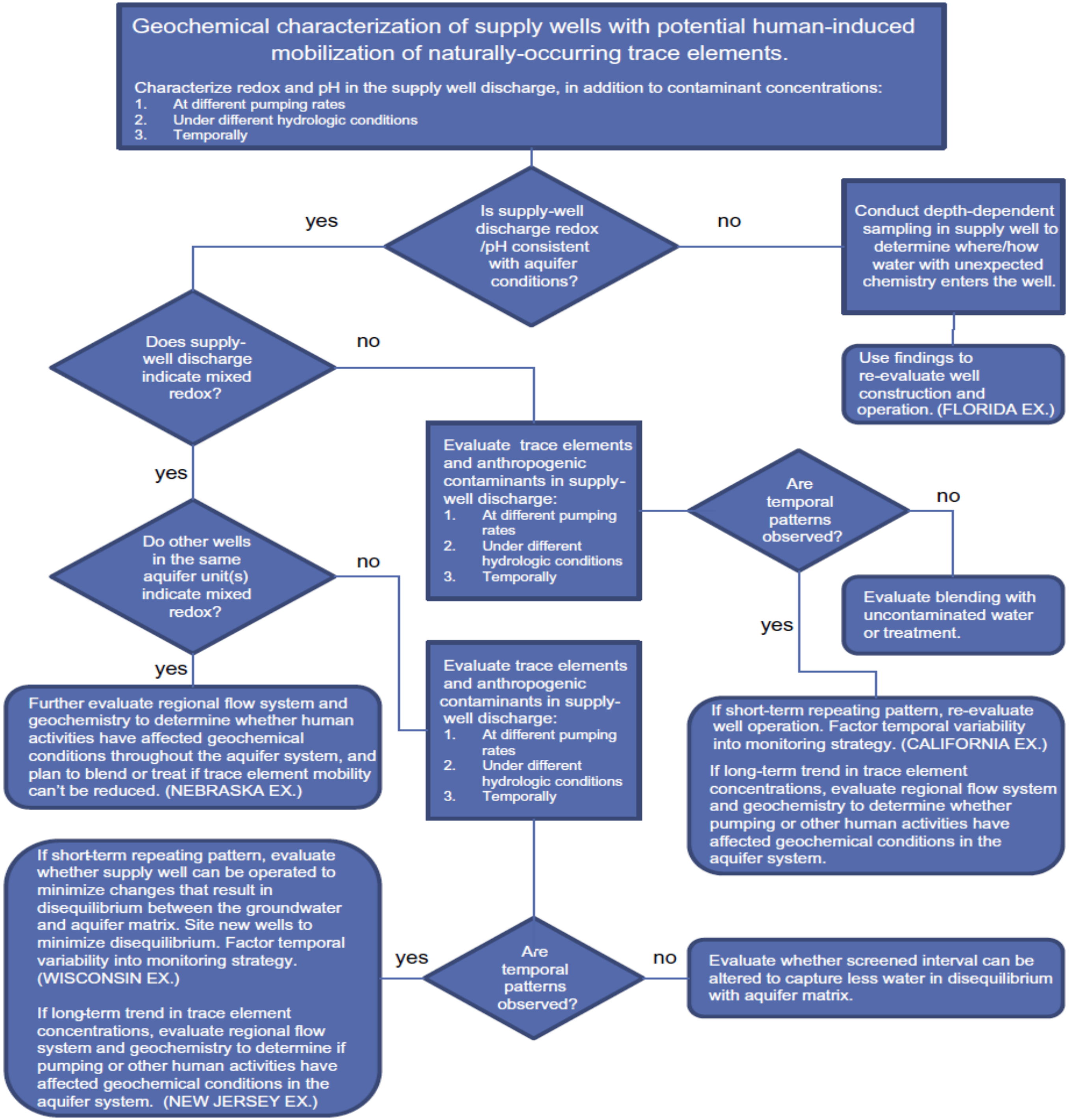

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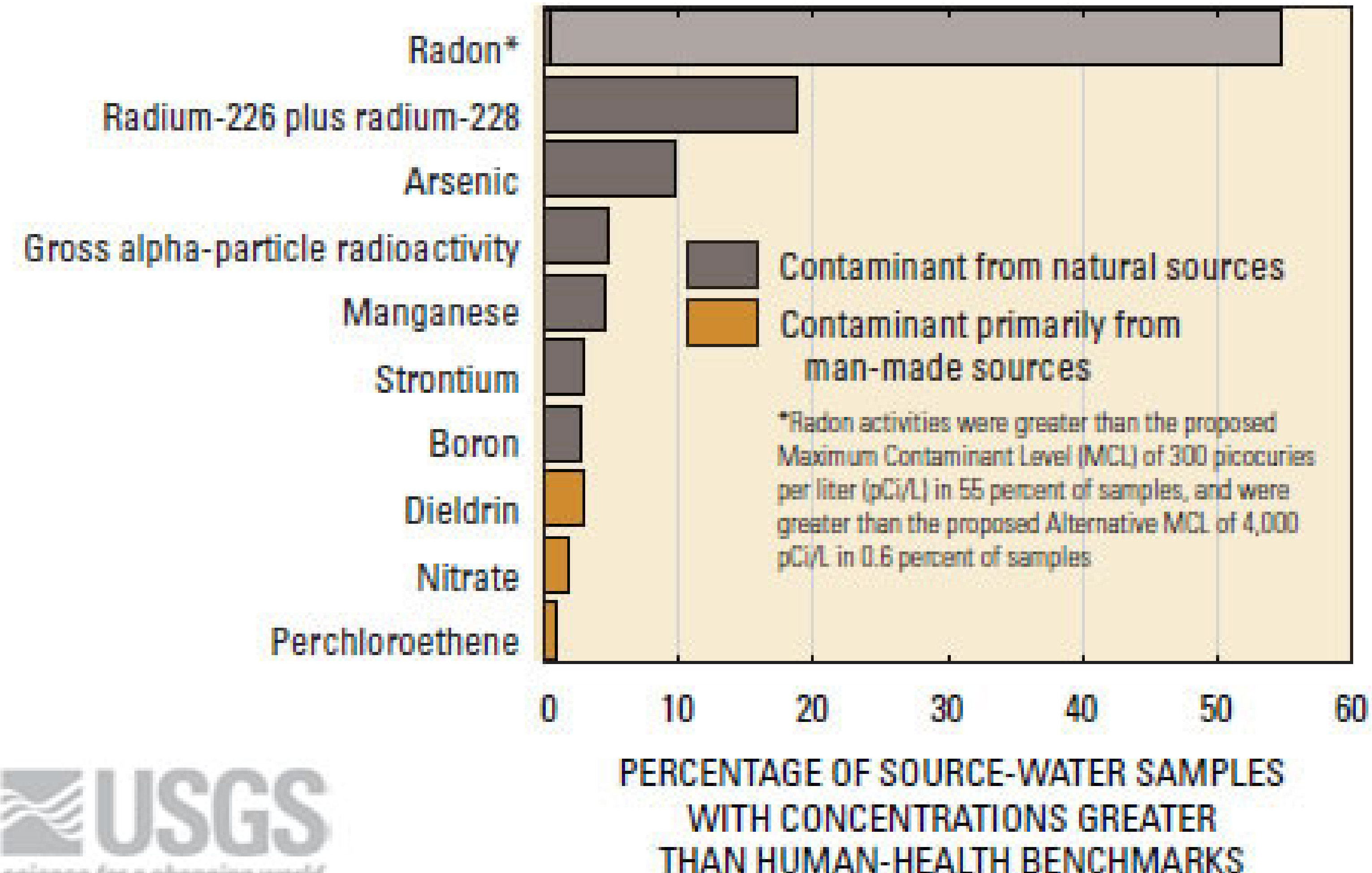

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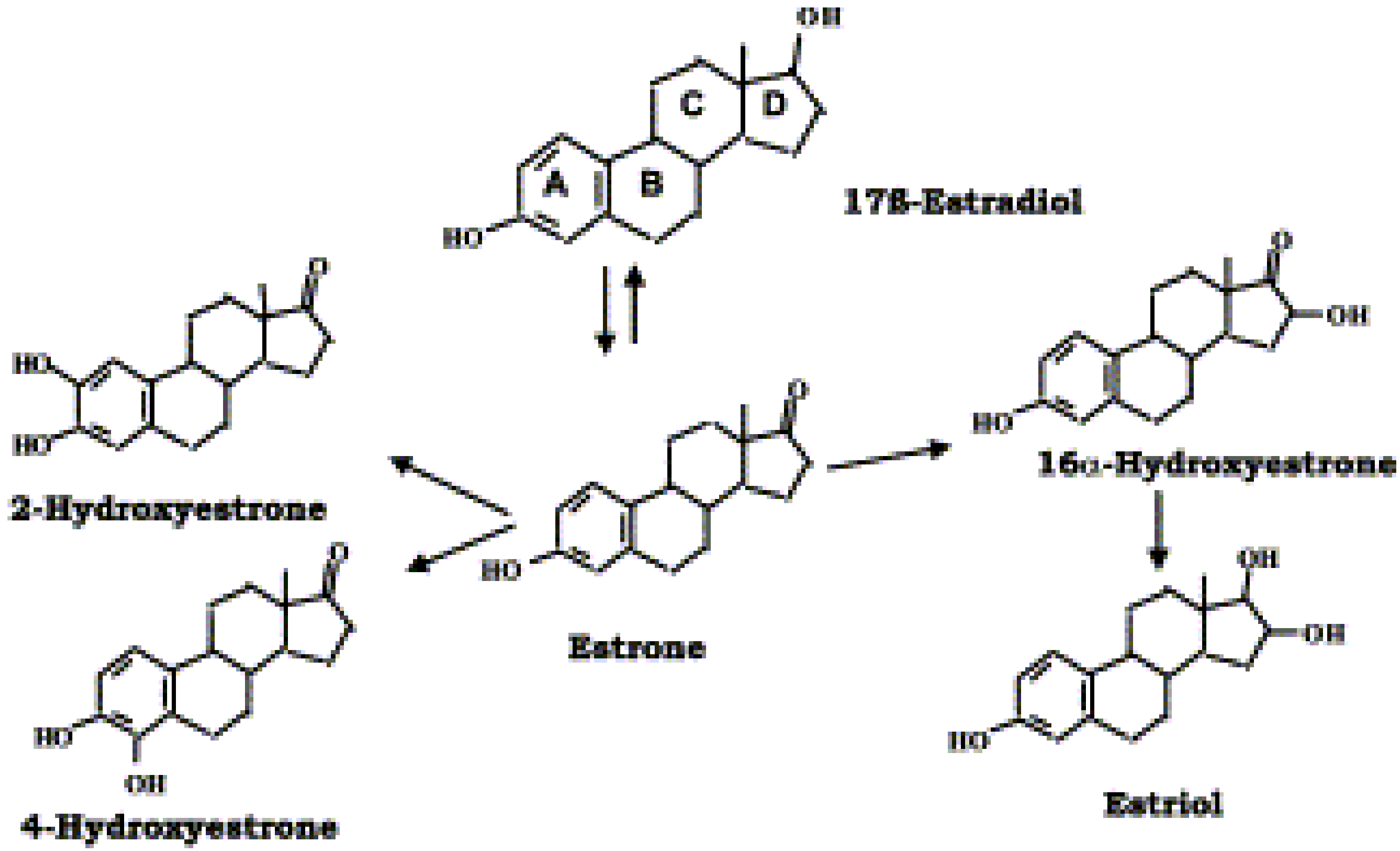
Toccalino et al., (2010)

19 basins sampled (avg DA = 4 mi^2)

- AR, IA, IN, KY, MD, MI, NC, NY, OH, PA, VA, WI

Animal Type	No. basins	No. animals
Grazing beef cattle	3	20 - 1500
Dairy	3	550 - 3000
Swine	5	1800 - 30000
Poultry	3	470000 - 800000
Confined beef	1	2000
Rural background	4	

37 water, 22 bed sediment, 23 manure, 19 POCIS, 31 QA/QC



A-ring metabolites

D-ring metabolites

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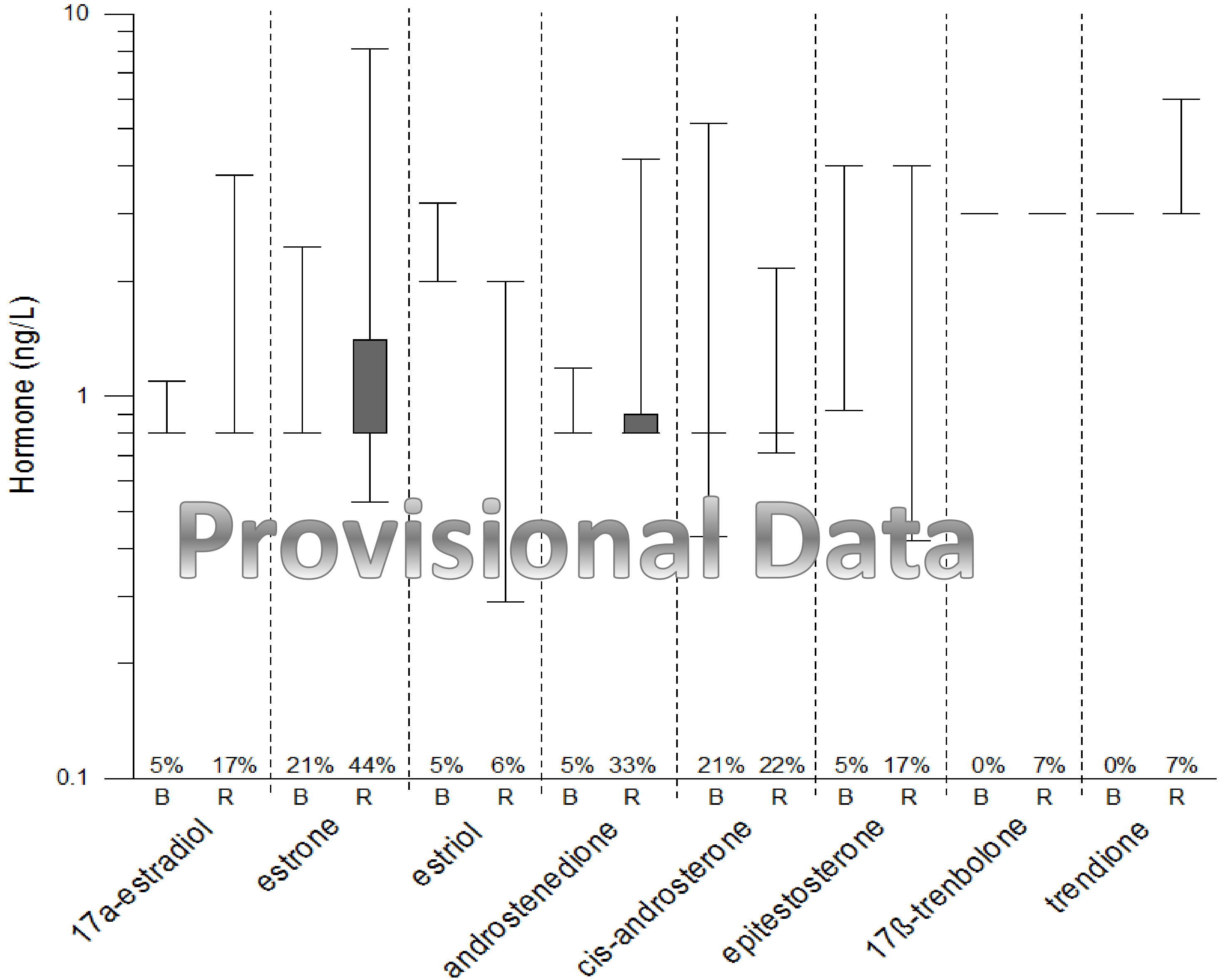
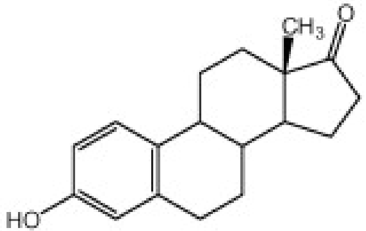
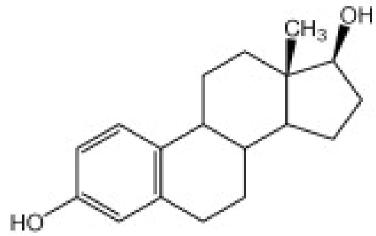


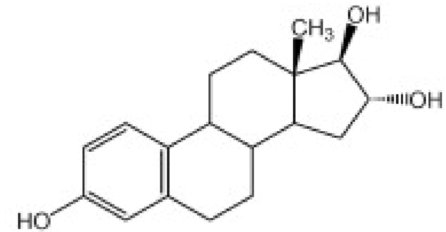
Hormone (ng/L)
10
1
0.1
Provisional Data
5% 17% 21% 44% 5% 6% 5% 33% 21% 22% 5% 17% 0% 7% 0% 7%
B R B R B R B R B R B R B R B R
17a-estradiol
estrone
estriol
androstenedione
cis-androsterone
epitestosterone
17ß-trenbolone
trendione



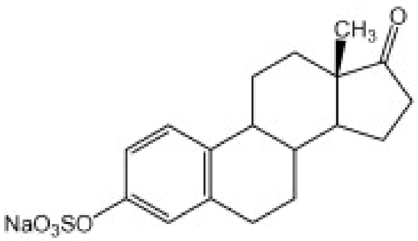
Estrone (E1)



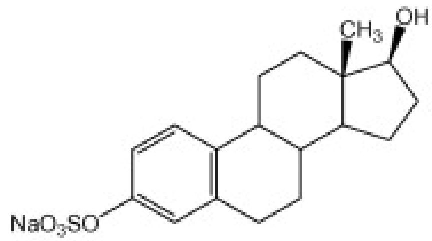
17 *β* -Estradiol (E2)



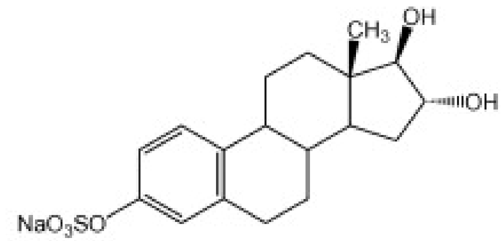
Estriol (E3)



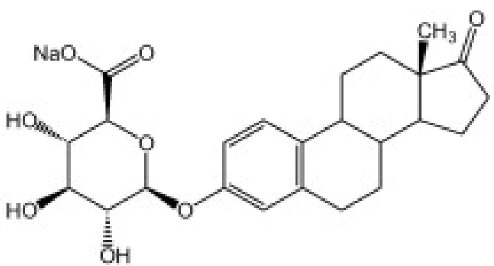
Estrone-3-sulfate sodium salt (E1-3S)



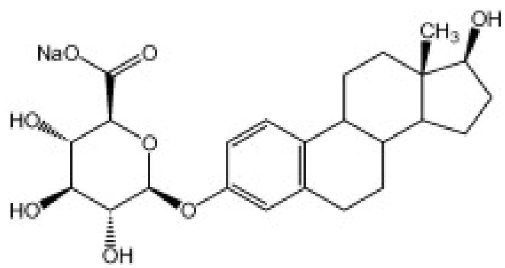
Estradiol-3-sulfate sodium salt (E2-3S)



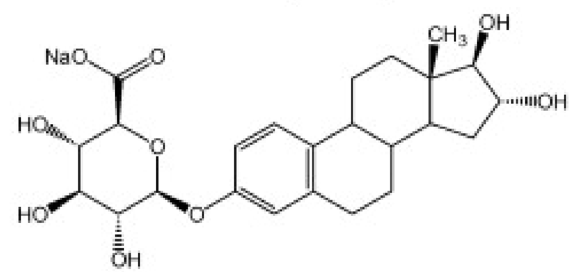
Estriol-3-sulfate sodium salt (E3-3S)



Estrone-3-glucuronide sodium salt (E1-3G)



Estradiol-3-glucuronide sodium salt (E2-3G)



Estriol-3-glucuronide sodium salt (E3-3G)

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Biogenic hormones are found in environmental settings where sources are concentrated such as wastewater effluents and livestock operations.

The detection frequencies and the concentrations are very low (sub nanogram/liter). Because hormones are active at these low levels impacts to stream biota are currently being investigated.

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Fate and transport of inorganics in the environment is dependent on the crustal abundance, element properties, local geochemical (pH, redox) and hydrogeological (proximity to natural or anthropogenic sources, residence time, flowpath) conditions. Sometimes one, or more, factor overrides the others thereby obfuscating predictive models.

Anthropogenic activities can impact redox controlled reactions thereby releasing more inorganic contaminants.

Strontium is the most mobile of the 6 UCMR inorganics with the highest crustal abundance.

Naturally occurring inorganics remain among the contaminants of most concern due to their prevalence, magnitude, and related toxicities.

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Thank you