APPENDIX G: TOXICS DISCUSSION

BACKGROUND

Concentrations of iron, manganese and arsenic in exceedance of State of Oregon water quality criteria have been observed in the Tualatin River and its tributaries. For the purpose of this paper, iron, manganese and arsenic have been collectively grouped together as "toxics" and further sub-classed as "metals". Currently, only Fanno Creek is included on Oregon's 1998 303(d) list for water toxics violations[1]. Toxics appear on the 303(d) list for Fanno Creek because they are detected in the water column at levels that exceed water quality criteria listed in Oregon Administrative Rules, Table 20. Arsenic concentrations exceed the criteria for the protection of human health from consumption of contaminated fish and water, while manganese and iron concentrations exceed criteria for the protection of domestic water supplies. Additional monitoring data indicate that many more stream segments within the Tualatin Basin exceed OAR Table 20 Standards for the above mentioned metals.

BENEFICIAL USES

Oregon Administrative Rules (OAR Chapter 340, Division 41, Table 6) lists the "Beneficial Uses" occurring within the Tualatin River Sub-Basin (**Table 1**). Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. Water and Fish Ingestion (arsenic) and Public and Private Domestic Water Supply (iron and manganese) are the most sensitive beneficial uses related to toxics in the Tualatin River Sub-Basin.

Table 1. Beneficial uses occurring in the Tualatin River Sub-Basin
(OAR 340 – 41 – 442)
Toxics-Sensitive Beneficial uses are marked in gray

Beneficial Use	***Occurring***	***Beneficial Use***	***Occurring***
Public Domestic Water Supply	✓	Salmonid Fish Spawning (Trout)	✓
Private Domestic Water Supply	✓	Salmonid Fish Rearing (Trout)	✓
Industrial Water Supply	✓	Resident Fish and Aquatic Life	✓
Irrigation	✓	Anadromous Fish Passage	✓
Livestock Watering	✓	Wildlife and Hunting	✓
Boating	✓	Fishing	✓
Hydro Power	✓	Water Contact Recreation	✓
Aesthetic Quality	✓	Commercial Navigation & Transportation	

[1] Oregon's 1998 303(d) list can be publicly accessed via the Internet at http://www.deq.state.or.us/

WATER QUALITY CRITERIA

Water quality criteria consist of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by U.S. Environmental Protection Agency (EPA) or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. The EPA standards for drinking water (reflected in OAR Table 20) fall into two categories – Primary Standards and Secondary Standards. Primary Standards are based on health considerations and are designed to protect people from three classes of pollutants: pathogens, radioactive elements and toxic chemicals. Arsenic is classified under Primary Standards, with a maximum of 2.2 ng/L ambient water concentration for consumption of both contaminated water and fish. Secondary Standards are based on taste, odor, color, and staining properties of water. Iron and manganese are both classified under the Secondary Standards, with limits of 300 μg/L and 50 μg/L**,** respectively. **Table 2** summarizes the toxics criteria for the Tualatin River Sub-Basin.

The State of Oregon adopted water quality criteria from the EPA guidance (1986). Criteria were adopted for specific parameters in order to protect the most sensitive beneficial uses of Oregon waterbodies. For instance, iron and manganese are not toxic at concentrations listed in OAR Table 20, but the aesthetic quality of drinking water is compromised at 300 μg/L for iron and 50 μg/L for manganese. The arsenic criterion is based upon a very conservative measure of toxicity, resulting in a very low criterion. The arsenic criterion (2.2 ng/L) was developed to protect the beneficial use of fish and water consumption.

Table 2. Toxics Information

Parameter	Criteria	Reference	Summary of Data
MANGANESE	50 μg/L	OAR Table 20, 1986 U.S. EPA Guidelines	Manganese found above water quality standard of 50 micrograms per liter in two samples collected by the USGS in 1993, (range 180 to 420 μg/L)
Iron	300 μg/L	OAR Table 20, 1986 U.S. EPA Guidelines	Iron found above water quality standard of 300 micrograms per liter in two samples collected by the USGS in 1993, (range 770 to 6000 μg/L)
Arsenic	2.2 ng/L	OAR Table 20, 1986 U.S. EPA Guidelines	Arsenic found above water quality standard of 2.2 *nanograms* per liter in two samples collected by the USGS in 1993, (range 1.0 to 2.0 μg/L)

Additional conditions in the State water quality standards pertinent to this TMDL are as follows:

OAR 340-41-445(2)(p)(A): Toxic substances shall not be introduced above natural background levels in the waters of the state in amounts, concentrations, or combinations which may be harmful, may chemically change to harmful forms in the environment, or may accumulate in sediments or bioaccumulate in aquatic life or wildlife to levels that adversely affect public health, safety, or welfare; aquatic life; wildlife; or other designated beneficial uses;

OAR 340-41-445(2)(p)(B): Levels of toxic substances shall not exceed the criteria listed in Table 20 which were based on criteria established by EPA and published in Quality Criteria for Water (1986), unless otherwise noted;

OAR 340-41-445(2)(p)(C): . . . Where no published EPA criteria exist for a toxic substance, public health advisories and other published scientific literature may be considered and used, if appropriate, to set guidance values.

OAR 340-41-445(3): Where naturally occurring quality parameters of waters of the Willamette River Basin are outside the numerical limits of the above assigned water quality standards, the naturally occurring water quality shall be the standard…

303(d) LISTED STREAM SEGMENTS

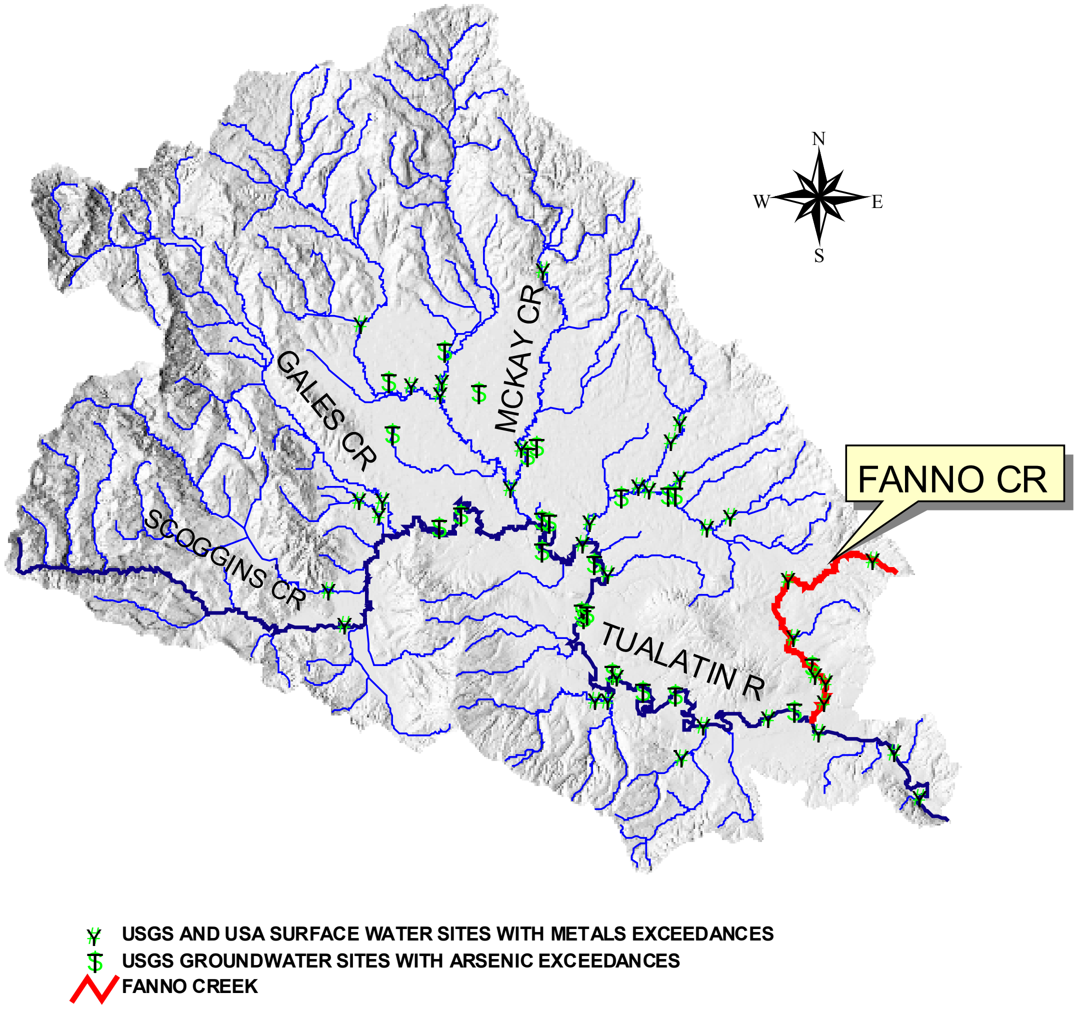
Section 303(d) of the Federal Clean Water Act (1972) requires that water bodies that violate water quality standards, thereby failing to fully protect beneficial uses, be identified and placed on the state's 303(d) list. The Oregon Department of Environmental Quality (DEQ) has developed four conditions to interpret and apply the toxics water quality criteria and determine impact on a beneficial use:

A. Water Quality Criteria Violations occur if:
   1. The freshwater chronic criteria for protection of aquatic life contained in OAR Table 20 is violated more than 10% of the time and for a minimum of two values. For hardness-dependent criteria, the criteria will be calculated based on the instream hardness measured at the time of sampling.
   2. The chemical is found in sediments at levels which analytical models demonstrate that water quality standards are violated. The analysis and modeling must be reviewed and approved by DEQ.

B. Measure of impairment of a Beneficial Use
   1. A fish or shellfish consumption advisory or recommendation issued by the Oregon State Health Division specifically refers to this chemical.
   2. The chemical has been found to cause a biological impairment via a field test of significance such as a bioassay. The field test must involve comparison to a reference condition.

Fanno Creek is the only water body in the Tualatin River Sub-basin that has been placed on the DEQ 1998 303(d) list for toxics. Fanno Creek was placed on the 303(d) list based upon data collected in 1993 by the United States Geological Survey (USGS) (Harrison *et* al 1995). Table 2 shows relevant toxics criteria and provides a brief description of the exceedances used to place Fanno Creek on the 303(d) list. Figure 2 shows the location of Fanno Creek within the Tualatin River Sub-Basin.

Figure 2. Tualatin Sub-Basin showing location of Fanno Creek and locations of Ground and Surface Water Metals Exceedances



AVAILABLE MONITORING DATA

As noted above, values from two samples collected in 1993 by the USGS were used to place Fanno Creek on the 303 (d) list for toxics (arsenic, iron and manganese). However, a significant number of surface water, groundwater, soil and fish tissue samples have been collected throughout the Tualatin River Basin by various agencies. Most notably, the USGS collected and analyzed water, soil and fish tissue samples as part of several studies conducted in the early 1990s and the Unified Sewerage Agency of Washington County (USA) has been regularly collecting and analyzing surface water samples for metals[2] since approximately 1990. Additionally, various regional and national studies have been conducted and are used in this document to provide numbers for comparison with local values. **Table 3** provides a summary of the local data and sources cited throughout this document.

Table 3. Sources of Tualatin Sub-Basin toxics data

[2] It should be noted that USA reports total metals as opposed to total recoverable metals.

	Date	Type	Source	Location	Number of Samples	Criteria	Median	Minimun	Maximum
Arsenic	1990-98	Surface Water	USA	Basin-wide	1140	2.2 ng/L	3.0 ug/L	0.0 ug/L	100 ug/L
	1992-96	Bed Sediment	USGS	Basin-wide	22		7.2 ug/g	2 ug/g	16 ug/g
	1991-93	Stormwater	Portland	Portland	2			6.0 ug/L	7.0 ug/L
	1992-96	Fish Tissue	USGS	Fanno, Cedar, Gales, and Rock Creeks	14		0.3 ug/g	0.2 ug/g	0.4 ug/g
Iron	1990-98	Surface Water	USA	Basin-wide	2398	300 ug/L	1080 ug/L	0.8 ug/L	52900 ug/L
	1992-96	Bed Sediment	USGS	Basin-wide	22		51500 ug/g	40000 ug/g	85000 ug/g
	Unknown	Groundwater	USGS	Basin-wide	Unknown		195-320 ug/L		
	1992-96	Fish Tissue	USGS	Fanno, Cedar, Gales, and Rock Creeks	14		91.1ug/g	56.1ug/g	279 ug/g
Manganese	1990-98	Surface Water	USA	Basin-wide	2108	50 ug/L	89.1 ug/L	0.8 ug/L	3210 ug/L
	1992-96	Bed Sediment	USGS	Basin-wide	22		1350 ug/g	850 ug/g	2700 ug/g
	1992-96	Fish Tissue	USGS	Fanno, Cedar, Gales, and Rock Creeks	14		31.4 ug/g	8.3 ug/g	88 ug/g

RELATIONSHIP BETWEEN ARSENIC, IRON AND MANGANESE

Iron and manganese exert a strong influence on arsenic concentrations in the environment. Arsenic can either be immobilized through adsorption-coprecipitation with iron and manganese under oxidizing conditions, or mobilized when iron and manganese are dissolved under reducing conditions. Within oxygenated zones (groundwater or surface water), arsenic V (arsenate) is stable and may sorb-coprecipitate with iron and manganese oxides if present. Under anoxic conditions, arsenic III (arsenite) is stable, and dissolved forms of iron and manganese are favored (Edwards 1994). It appears that arsenic, iron and manganese are mobilized in Tualatin Sub-Basin groundwater due to their presence within local alluvial deposits and the predominance of reducing conditions within associated aquifers. Relatively high concentrations of naturally occurring arsenic are common in the Southwest and Northwest United States. These occurrences tend to be sporadic because arsenic is mobilized only under a narrow range of oxidation/reduction (redox) conditions. The reducing conditions must be sufficient to reduce and dissolve iron and manganese but not to produce sulfide (Korte 1991). Consequently, groundwater samples containing elevated levels of arsenic typically also contain elevated levels of iron and manganese and little or no dissolved oxygen. Anderson and Bruland (1991) noted a similar relationship in surface waters, with elevated concentrations of arsenic, iron and manganese occurring in the absence of dissolved oxygen.

Arsenic

Arsenic is a ubiquitous, naturally occurring element. Increased levels of arsenic in water and soil are commonly a result of leaching from arsenic-rich geologic layers into ground water. In addition, nonferrous mining and smelting operations, refining operations and pesticide manufacturing facilities may add to increased levels of arsenic in water. Only very limited quantities of arsenic-containing pesticides are still manufactured and used under strict limitations in the U.S. They represent a minimal source of arsenic exposure.
The EPA has classified arsenic as a known carcinogen. Sources of human exposure to arsenic compounds may include air, soil, water and food. Dietary sources may include dairy products, meat, poultry and fish, fruits and vegetable and grain products.

Arsenic may exist in both an organic and inorganic form, either in the trivalent (arsenite) or pentavalent (arsenate) oxidation state. As shown in the diagram below, arsenite tends to predominate under reducing conditions and arsenate tends to predominate under oxidizing conditions (Hinkle and Polette 1999, Anderson and Bruland 1991).

oxidation
trivalent-------------->pentavalent
(arsenite)<--------------(arsenate)
reduction

Trivalent forms of arsenic (inorganic and organic) are more toxic to humans and aquatic organisms and are usually only present under anaerobic conditions. Webb (1966) found that arsenite is approximately 60 times more toxic to humans than arsenate. With few exceptions, inorganic arsenic is more toxic than organic arsenic. Inorganic forms of arsenic dissolved in drinking water are the most significant forms of natural exposure.
Ferguson and Gavis (1972) concluded that it is unlikely that consumption of arseno-organic compounds in fish or other organisms will constitute a hazard from arsenic poisoning. Rather, the potential hazard is in the consumption of water containing high concentrations of inorganic arsenite.

REGULATORY BACKGROUND

The State of Oregon currently uses the arsenic standards promulgated by the EPA in "Quality Criteria for Water, 1986". As mentioned above, the State of Oregon adopts the most stringent criteria applicable to protect the beneficial uses of a waterbody. The most sensitive beneficial uses in the Tualatin River Basin are water and fish consumption, which necessitates a water quality criterion of 2.2 *nanograms* per liter for the protection of human health. The EPA Office of Water also has a drinking water standard, or maximum contaminant level (MCL) issued under the Safe Drinking Water Act of 50 µg/L. The EPA Office of Water has been in the process of reevaluating the MCL and will likely substantially reduce the current standard.

In I992, EPA promulgated a final rule (known as the National Toxics Rule) to establish numeric water quality criteria for 12 States and 2 Territories that had failed to comply fully with section 303(c)(2)(C) of the CWA. The 1992 rule established a standard of 0.018 µg/L to protect those who consume the water and who also consume fish. As a relative comparison, arsenic concentrations derived from unpolluted oceanic air masses average 0.019 µg/L (Welch *et al* 1988). For fish consumption only, the standard was set at 0.14 µg/L. These arsenic water quality criteria represent a one in one million (10^{-6}) cancer risk level for arsenic exposures and refers to the **inorganic form only**. Criteria based on inorganic arsenic are difficult to regulate and require additional resources for water quality analyses. The criteria used by the State of Oregon are based on total arsenic and do not allow for adjustments to account for the organic form.

ARSENIC IN GROUND WATER:

In a study of arsenic in groundwater of the Western United States, Welch *et al* (1988) noted that elevated arsenic concentrations (greater than 50 µg/L) are commonly associated with alluvial sediments similar to those found in the Tualatin River Basin. Hinkle and Polette (1999) observed that arsenic concentrations exceeding the EPAs current drinking water standard of 50 µg/L are widespread in groundwater throughout the Willamette Basin and the standard is "routinely exceeded" in the Tualatin Sub-Basin. They also noted that high arsenic levels in Tualatin Basin groundwater are associated with alluvial geologic deposits and are "not consistent with either industrial or agricultural sources of arsenic".

The general spatial distribution for groundwater arsenic samples with concentrations greater than 11 µg/L collected by the USGS in the Tualatin ub-Basin is shown in **Figure 2**.
The USGS data was broken down into three groups: less than 10 µg/L, 11 to 50 µg/L, and greater than 50 µg/L. Because the "less than 10 µg/L" group potentially contains observations that are below EPA and DEQ water quality criteria, only observations in the latter two groups are depicted in **Figure 2**.

ARSENIC IN SOIL AND BED SEDIMENTS:

For purposes of comparison, natural soil arsenic concentrations in Washington State average between 5.1 and 9.3 μg/g. In Clark County, just across the border with Oregon, concentrations average 5.8 μg/g (Juan 1994). Alloway (1990) reported the overall mean arsenic concentration for 2691 uncontaminated soil samples (taken in England) was 10 μg/g. Based upon an average of sites sampled statewide, the State of Oregon reported a range of naturally occurring background concentrations for soil arsenic between 1 and 10 μg/g (Baldwin and McCreary 1998). Bonn (1999) reported arsenic concentrations for 22 bed sediment samples taken from tributaries throughout the Tualatin River Sub-Basin between 1992 and 1996. The median, minimum and maximum arsenic concentrations were 7.2 μg/g, 2.0 μg/g, and 16.0 μg/g, respectively (**Table 4**). Based upon this comparison, it appears likely that arsenic concentrations in Tualatin River Basin bed sediment are at or near background levels.

Table 4. Metals Concentrations found in Tualatin River Sub-Basin Bed Sediment (Bonn 1999)

Sampling Location	Date	Arsenic (µg/g)*	Iron (mg/g)*	Manganese (µg/g)*
Ash Cr. at Greenburg Rd.	09/14/92	16	51	1300
Beaverton Cr. at Cedar Hills Blvd	08/29/96	9.3	52	1900
Beaverton Cr. at Cedar Hills Blvd	08/29/96	9.5	52	1900
Bronson Cr. at Walker Rd.	09/16/92	5.2	40	1400
Cedar Mill Cr. at Jenkins Road	09/18/92	4.4	42	1000
Chicken Cr. near Sherwood, OR	09/18/92	6.8	53	2200
Dairy Cr. at Susbauer Road	09/15/92	7.4	51	1200
Fanno Cr. near Denny Road	08/29/96	4.3	42	1000
Fanno Cr. near Denny Road	08/29/96	4.3	42	1000
Fanno Cr. at Durham	09/01/92	8.6	56	1700
Fanno Cr. at Durham	10/01/93	9.9	55	2700
Fanno Cr. at Durham	10/01/93	12	55	2300
Fanno Cr. at Durham	10/01/93	7.3	61	1400
Upper Fanno Cr. at Nicol Road	09/14/92	3.5	43	880
Gales Cr. near Glenwood	09/09/92	2	85	1300
McKay Cr. at Hornecker Road	09/15/92	10	54	1500
Lower Rock Cr. at Brookwood Rd.	09/17/92	7.1	41	1000
Lower Rock Cr. at Brookwood Rd.	09/17/92	6.6	40	850
Lower Rock Cr. at Brookwood Rd.	09/17/92	7.2	41	1100
Upper Rock Cr. at Baseline Road	09/16/92	6.8	40	1500
Tualatin River above Dairy Creek	09/22/92	3.8	67	1400
Tualatin River at Elsner Road	09/21/92	8.0	59	1200
* Minimum Reporting Limit (MRL): As = 0.1, Fe = 0.05, Mn = 4.0	**Median**	**7.2**	**51.5**	**1350**
	Minimum	**2**	**40**	**850**
	Maximum	**16**	**85**	**2700**

ARSENIC IN SURFACE WATER:

Nationally, approximately 21 percent of stream and river samples collected by the USGS in a 1969 study had arsenic concentrations above 10 µg/L (Welch *et al* 1988). No data was given as to the suspected source of surface water arsenic, other than to note that it is "unusual to find high arsenic concentrations in river water without a significant contribution of arsenic from geothermal water or mineralized areas". Edwards (1994) reported that a random survey of raw drinking water sources in the United States resulted in an average arsenic concentration of 4 µg/L. The general spatial distribution for USGS-collected surface water samples with metals concentrations greater than OAR Table 20 standards is shown in **Figure 2**. Samples were collected by the USGS and USA, with values reported in Harrison *et al* (1995), Tetra Tech (1992) and in the U.S. Environmental Protection Agency's (EPA) STORET[3] database. This pattern indicates that, based upon current data, metals concentrations at least occasionally exceed standards throughout much of the Tualatin Sub-Basin. Basin-wide surface water samples collected by USA show a median arsenic concentration of 3.0 µg/L, based upon 1140 samples (**Table 3**). While arsenic concentrations in Tualatin Sub-Basin surface waters are high relative to the OAR Table 20 criteria, they appear to be at or below national averages and likely reflect natural background arsenic concentrations.

ARSENIC IN FISH TISSUE:

Fish tissue data can provide the most reliable evidence of impairment of beneficial uses by toxics in the Tualatin River Sub-Basin. Most of the available fish tissue data were collected in the summers of 1992-96 as part of cooperative study conducted by the USGS and USA (Bonn 1999). Fourteen fish (sculpin) tissue samples were collected at various locations within the Tualatin Sub-Basin between 1992 and 1996. Samples were analyzed for various organic chemicals and metals, including arsenic, iron and manganese. Different organisms can be expected to bioaccumulate chemicals differently based on age, life cycle patterns, amount of fatty tissue and feeding habits. It is therefore necessary to make certain assumptions when comparing arsenic concentrations from one species (sculpin) to other fish and shellfish, namely that the species are similar enough in habit and physiology to make valid comparisons. **Table 5**, summarized from Bonn (1999), shows median, minimum and maximum fish tissue arsenic concentrations of 0.3 µg/g, 0.2 µg/g, and 0.4 µg/g, respectively. Arsenic concentrations reported in **Table 5** are for total arsenic.

[3] Information on how to access the EPA STORET database can be publicly accessed via the Internet at: http://www.epa.gov/owowwtr1/STORET/index.html

Table 5. Metals Concentrations found in Tualatin River Sub-Basin Fish Tissue (Bonn 1999)				
Sampling Location	**Date**	**Arsenic (µg/g)***	**Iron (µg/g)***	**Manganese (µg/g)***
Cedar Mill Cr. at Jenkins Road	09/05/96	0.4	66.3	17.3
Dairy Cr. at Susbauer Road	08/19/96	Non detect	61.3	22.2
Fanno Cr. near Denny Road	09/04/96	0.2	134	36.6
Fanno Cr. near Denny Road	09/04/96	Non detect	57.4	23.9
Fanno Cr. near Denny Road	09/04/96	Non detect	97.9	50
Fanno Cr. at Durham	09/01/92	0.4	110	51.1
Fanno Cr. at Durham	09/29/93	0.3	279	78.1
Fanno Cr. at Durham	09/29/93	0.3	183	49.9
Fanno Cr. at Durham	09/29/93	0.4	237	88
Fanno Cr. at Durham	08/20/96	0.3	80.2	27.1
Upper Fanno Cr. at Nicol Road	08/20/96	0.2	84.3	34.9
Gales Cr. near Glenwood	09/09/92	Non detect	216	8.3
Gales Cr. near Glenwood	08/19/96	Non detect	81.1	9.7
Upper Rock Cr. at Baseline Road	08/21/96	0.2	56.1	27.9
* Minimum Reporting Limit (MRL): As = 0.2, Fe = 1.0, Mn = 0.1	**Median**	**0.3**	**91.1**	**31.4**
	Minimum	**0.2**	**56.1**	**8.3**
	Maximum	**0.4**	**279**	**88**

The DEQ often relies on recommendations made by the Oregon Health Division when determining if pollutants are potentially harmful to human health. According to Oregon Listing Criteria for 1994/1996 Section 303(d) list (June 1996), DEQ uses fish or shellfish consumption advisories issued by the Oregon State Health Division to indicate impairment of a beneficial use. The Oregon Health Division, using EPA's reference dose of 0.001 mg/kg/day, determined that human risks from organic arsenic in fish tissues are not cause for concern until arsenic levels exceed "several" micrograms per gram (Duncan Gilroy, Public Health Toxicologist, Oregon Health Division, personal communication, 1/13/00). In a letter dated March 27, 1997 Gilroy notes:

> "Arsenic levels of parts per million (range) are commonly found in fish and shellfish. Assessments of fish consumption risks often don't speciate arsenic, assuming all fish arsenic is inorganic arsenic. This is a very protective approach, as most arsenic in fish (80-90%) is relatively nontoxic organic form."

Since most of the arsenic present in fish is in the organic form, criteria can be modified to reflect this. One methodology for calculating acceptable arsenic levels in surface water can be found in the "Guidance Document for Arsenic in Shellfish".[4] The guidance states (in part) that based upon average consumption of 15 grams/person/day, and assuming that 10% of the total arsenic in shellfish is inorganic, the tissue level of concern would be 86 μg/g (considerably higher than the 0.3 μg/g fish tissue concentrations found in the Tualatin Sub-Basin).

IRON

Elevated iron concentrations in surface and ground water is a very common problem. Iron occurs naturally in many alluvial sediments of volcanic origin, like those found in the Tualatin River Sub-Basin. At this time there are no known health effects from elevated levels of iron in drinking water, but aesthetic water quality degradation (taste and odor) occurs at levels above 300 μg/L. According to the EPA, iron is not a known carcinogen, suspected carcinogen, or a pollutant known to be seriously toxic at low levels.

IRON IN GROUND WATER:

As noted above, Korte (1991) noted that groundwater samples containing elevated levels of arsenic typically contain elevated levels of iron and manganese and little or no dissolved oxygen. Kelly *et al*. (1999) found median iron concentrations of 195 μg/L and 320 μg/L in Tualatin River Sub-Basin shallow and deep groundwater, respectively.

IRON IN SOILS AND BED SEDIMENTS:

Bonn (1999) reported iron concentrations for 22 bed sediment samples taken from tributaries throughout the Tualatin River Sub-Basin between 1992 and 1996. The median, minimum and maximum iron concentrations were 51.5 mg/g, 40 mg/g, and 85 mg/g, respectively (**Table 4**). Juan (1994) found that natural background iron concentrations in Washington State average between 25.0 and 58.7 mg/g. In Clark County, just across the border with Oregon, levels average 36.1 mg/g. Based upon this comparison, it is assumed that iron concentrations in Tualatin River Basin bed sediment are at or near background levels.

IRON IN SURFACE WATER:

Basin-wide surface water samples collected by USA show a median iron concentration of 1080 μg/L, based upon 2398 samples (**Table 3**). The general spatial distribution for surface water samples with metals concentrations greater than OAR Table 20 criteria is shown in **Figure 2**. Samples were collected by the USGS and USA, with values reported in Harrison *et al* (1995), Tetra Tech (1992) and in the EPA STORET database. This pattern indicates that, based upon current data, metals concentrations periodically exceed criteria throughout much of the Tualatin Basin. While iron concentrations in Tualatin Sub-Basin surface waters are high relative to the OAR Table 20 criteria, they likely reflect natural background iron concentrations.

IRON IN FISH TISSUE:

Table 5, summarized from Bonn (1999), shows median, minimum and maximum fish tissue iron concentrations of 91.1 μg/g, 56.1 μg/g, and 279.0 μg/g, respectively.
Iron is not known to be toxic to humans through consumption of fish tissue. It is difficult to compare Tualatin Sub-Basin fish tissue iron concentrations to fish from other regions or to make any conclusions based on the numbers in **Table 5**.

[4] The "Guidance Document for Arsenic in Shellfish", produced by the U.S. Food and Drug Administration, can be publicly accessed via the Internet at http://vm.cfsan.fda.gov/~frf/guid-as.html

Manganese

High concentrations of manganese in surface and ground water is a common, naturally occurring phenomena but can also be introduced by industry. It can produce a brownish-black discoloration and can produce an unpleasant odor and taste. At this time there are no known health effects from elevated levels of manganese in drinking water, but aesthetic water quality degradation (taste and odor) occurs at levels above 50 µg/L. Manganese in drinking water is not considered a health hazard except at extremely high concentrations.

MANGANESE IN GROUND WATER:

As noted above, Korte (1991) noted that groundwater samples containing elevated levels of arsenic typically contain elevated levels of iron and manganese and little or no dissolved oxygen. However, no data on groundwater manganese concentrations in the Tualatin Sub-Basin were readily available for inclusion in this document.

MANGANESE IN SOILS AND BED SEDIMENTS:

Manganese concentrations in volcanically derived soils generally range between 200 µg/g and 1000 µg/g (Alloway *et al* 1990). Juan (1994) found that natural background manganese concentrations in Washington State average between 700 and 1500 µg/g. In Clark County, just across the border with Oregon, levels average 1500 µg/g. Bonn (1999) reported manganese concentrations for 22 bed sediment samples taken from tributaries throughout the Tualatin River Basin between 1992 and 1996. The median, minimum and maximum arsenic concentrations were 1350 µg/g, 850 µg/g, and 2700 µg/g, respectively (**Table 4**). Based upon this comparison, manganese concentrations in Tualatin River Sub-Basin bed sediment appear to be at or near background levels.

MANGANESE IN SURFACE WATER:

Basin-wide surface water samples collected by USA show a median manganese concentration of 89.1 µg/L, based upon 2108 samples (**Table 3**). The general spatial distribution for surface water samples with metals concentrations greater than OAR Table 20 criteria is shown in **Figure 2**. Samples were collected by the USGS and USA, with values reported in Harrison *et al* (1995), Tetra Tech (1992) and in the EPA STORET database. This pattern indicates that, based upon current data, metals concentrations periodically exceed criteria throughout much of the Tualatin Sub-Basin. While manganese concentrations in Tualatin Sub-Basin surface waters are high relative to the OAR Table 20 criteria, they likely reflect natural background manganese concentrations.

MANGANESE IN FISH TISSUE:

Table 5, summarized from Bonn (1999), shows median, minimum and maximum fish tissue manganese concentrations of 31.4 µg/g, 8.3 µg/g, and 88.0 µg/g, respectively. Manganese is not known to be toxic to humans through consumption of fish tissue. It is difficult to compare Tualatin Sub-Basin fish tissue manganese concentrations to fish from other regions or to make any conclusions based on the numbers in **Table 5**.

ANTHROPOGENIC SOURCES OF ARSENIC

Arsenical pesticides have most certainly been used in the agricultural portions of the Tualatin Sub-Basin, and industrial sources have released arsenic into localized areas around their facilities[5]. However, all known anthropogenic sources of arsenic (contaminated sites) have been cleaned up or are currently in the cleanup process. At this time there is no indication that any of the sites are contributing excess (above natural background levels) arsenic to surface waters.

Regional patterns of arsenic occurrence in Tualatin Sub-Basin ground water are not consistent with either industrial or agricultural sources of arsenic. This argument is further bolstered by the fact that no obvious relation of arsenic concentration to well depth was observed in the Tualatin Sub-Basin (Hinkle and Polette 1999). If arsenical pesticide application were responsible for elevated levels of arsenic in groundwater, a pattern of higher concentrations in shallow groundwater and lower concentrations in deep groundwater would likely be evident.

In the following excerpt, Hinkle and Polette explain why they ascribed high arsenic levels to natural sources:

> *"In contrast to land-use patterns in the bedrock areas of Lane and Linn Counties, land use in alluvial portions of the Tualatin Basin includes a variety of agricultural land uses, and high-arsenic ground water in alluvium in the Tualatin Basin does generally coincide with occurrence of agricultural areas. Closer inspection of the data, however, shows that detections of high concentrations of arsenic in Tualatin Basin ground water generally are near rivers and streams. Ground water near these rivers and streams likely represents ground water near the end of ground-water flowpaths. Occurrence of high concentrations of arsenic in downgradient parts of ground-water flowpaths could result from transport of arsenic from upgradient areas where arsenical pesticides historically had been applied, or from mobilization of naturally occurring arsenic during geochemical evolution as ground water moves along flowpaths. Arsenic is nearly immobile in top-soils, and arsenic in arsenical-pesticide-contamnated topsoil leaches on timescales of decades or more (Aten and others, 1980). Thus, occurrence of high concentrations of arsenic primarily in down-gradient areas, and not more uniformly distributed in the Tualatin Basin, is more consistent with a natural source than an anthropogenic source."*

In short, Hinkle and Polette observed that arsenic concentrations did not increase with well depth, but tended to increase as you moved downgradient within an aquifer due to an arsenic-rich geochemical environment within the aquifer.

SUMMARY

Exceedances of water quality criteria for arsenic, iron and manganese are common throughout the Tualatin Sub-Basin. It appears that arsenic, iron and manganese are mobilized in Tualatin Basin groundwater due to their natural presence within local alluvial deposits and the predominance of reducing conditions within associated aquifers. Surface water concentrations of arsenic, iron and manganese appear to be a reflection of the natural geochemical environment and regional groundwater hydrology within the Tualatin Sub-Basin. The USGS (Hinkle and

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[5] A complete list of known and suspected contaminated sites is available for public viewing using the Environmental Contaminant Site Information (ESCI) database at the Oregon Department of Environmental Quality, Northwest Region, 2020 SW 4th Ave., Suite 400, Portland OR.

Polette 1999) concluded that regional patterns of arsenic occurrence in Tualatin Sub-Basin ground water are not consistent with either industrial or agricultural sources of arsenic. The Oregon Department of Health has determined that human risks from organic arsenic in fish tissues are not cause for concern at the levels reported in the Tualatin Sub-Basin. While surface water concentrations are high relative to water quality criteria, they are on par with national averages and most likely reflect natural background conditions. At this time the DEQ feels that a TMDL for toxics is not necessary. Rather, water quality standards for arsenic, manganese and iron will be re-evaluated and possibly revised to reflect natural background concentrations as prescribed in OAR 340-41-445(3), above. This work will be done in a future triennial standards review.

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