Moore-Love, Karla

From: Jeya Aerenson <jeya812@gmail.com>
Sent: Thursday, April 23, 2015 8:32 AM
To: Council Clerk – Testimony
Subject: April 23 meeting - Washington Park

Dear City Council members,

I am writing regarding the proposed demolition of the Washington Park reservoirs.

With all of the infrastructure projects that Portland needs, one has to question why and how this Washington Park destruction solution, with it's exorbitant cost, has become priority for the city. This is yet another project that is being rushed through the City Council process with a disregard for the long term scientific, social, and economic impact to the Portland community.

There is no need to expedite this project! There are less extreme and less costly solutions available for the Washington Park reservoirs in order to protect the land from possible environmental issues. By waiting until the EPA LT2 ruling in 2016 the City could save tens of millions of dollars on just this project. This will allow the time needed to fully explore all options, including those that will be presented in the April 23 City Council meeting.

Sincerely,

Jeya Aerenson, OMD

Moore-Love, Karla

From: Kate & Chris <samsa@pacifier.com>
Sent: Thursday, April 23, 2015 6:44 AM
To: Council Clerk – Testimony; Moore-Love, Karla
Subject: Fw: Cicerone Radon and Earthquakes Article--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm
Attachments: 2009-06-13 Paper--Cicerone Radon As Earthquake Detector.pdf

Re-trying, as my first attempt may have omitted the attachment. Thank you for your patience with these many submissions; e-mail servers are very testy about how much they will let one send. --K

From: Kate & Chris
Sent: Thursday, April 23, 2015 2:53 AM
To: cctestimony@portlandoregon.gov ; karla.moore-love@portlandoregon.gov
Subject: Re: Cicerone Radon and Earthquakes Article--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

Please let the record show that the attached peer-reviewed Tectonophysics publication describes radon outgassing into groundwater, such as that of Portland's backup source at the Columbia South Shore Well Field, as a risk that is greatly enhanced by even slight seismic activity; such that groundwater radon concentration monitoring is a leading prognosticator of seismic events; and radon contamination can increase during events up to 12000% of baseline levels.

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

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Review article

A systematic compilation of earthquake precursors

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ABSTRACT

A survey of published scientific literature was undertaken to identify and catalog observed earthquake precursors. The earthquake precursors selected for analysis included electric and magnetic fields, gas emissions, groundwater level changes, temperature changes, surface deformations, and seismicity. For each of these precursors, the published scientific literature was searched to document the statistics of each reported earthquake precursor (spatial extent, time, duration, amplitude, signal/noise ratio), to analyze dependence of the observable for each precursor on earthquake magnitude, and to explore proposed physical models to explain each earthquake precursor. Some general characteristics were observed for these precursory phenomena. First, the largest amplitude precursory anomalies tend to occur before the largest magnitude earthquakes. Also, the number of precursory anomalies tends to increase the closer in time to the occurrence of the earthquake. Finally, the precursory anomalies tend to occur close to the eventual epicenter of the earthquake. In general, the physical models indicate that all of the precursory phenomena are related to deformation that occurs near the fault prior to the main earthquake. While the models provide plausible physical explanations for the precursors, there are many free parameters in the models that are poorly resolved.

Contents

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1. Introduction

One of the more elusive goals in seismology is short-term earthquake prediction. By the mid 1970s, seismologists were confident that short-term earthquake prediction would be achieved within a short period of time. This confidence came about in part as the result of the first successful prediction of a large earthquake, the 1975 M7.4 Haicheng earthquake in China. Because of this prediction, an alert was issued within the 24-hour period prior to the main shock, probably preventing a larger number of casualties than the 1328 deaths that actually occurred from this event. However, the failure to predict another devastating earthquake 18 months later, the 1976 M7.8 Tangshan earthquake, was a major setback to the earthquake prediction effort. Casualties from this earthquake numbered in the hundreds of thousands. A summary of these events, as well as other successes and failures in earthquake prediction, is given by Lomnitz (1994).

One area that may hold promise in advancing the science of short-term earthquake prediction is the study of earthquake precursors. In fact, short-term predictions are typically based on observations of these types of phenomena. The term *earthquake precursor* is used to describe a wide variety of physical phenomena that reportedly precede at least some earthquakes. These phenomena include induced electric and magnetic fields, groundwater level changes, gas emissions, temperature changes, surface deformations, and anomalous seismicity patterns. While each of these phenomena has been observed prior to certain earthquakes, such observations have been serendipitous in nature. For example, anomalous magnetic fields were recorded prior to the 1989 Loma Prieta earthquake in California by a magnetometer installed to monitor electromagnetic noise produced by electric trains. Fortuitously, this magnetometer was located within 7 km of the epicenter of the Loma Prieta earthquake (Fraser-Smith et al., 1990). The magnetometer detected two precursory magnetic fields, the first approximately 2 weeks prior to the main shock and the second approximately 3 h before the main shock.

More recently, attempts have been made to monitor various precursory phenomena as part of an overall earthquake prediction effort. The Parkfield, CA experiment (Bakun and Lindh, 1985) is one such experiment. A wide array of geophysical instruments was installed along a segment of the San Andreas Fault in central California (the so-called Parkfield segment) in 1981. These instruments included magnetometers, water level monitors, creepmeters, and straimeters and were designed to record a wide variety of precursory phenomena. Based on magnitude 6+ earthquakes on the San Andreas Fault at Parkfield from 1857 to 1966, the United States Geological Survey (USGS) issued an official prediction of a M6 earthquake along this segment in 1985, to occur with 95% probability before the end of 1993 (Working Group on California Earthquake Probabilities, 1988). This earthquake did not occur until late 2004, and no precursory phenomena of significance were observed. A preliminary report on this earthquake and its lack of precursors is given by Langbein et al. (2005).

The purpose of this study was to carry out a survey of published scientific literature to identify and catalog observed earthquake precursors that have been published. In this work we identified several types of earthquake precursors and searched the published scientific literature to carry out the following tasks:

- Document the statistics of each reported earthquake precursor (spatial extent, time, duration, amplitude, signal/noise ratio)
- Analyze the dependence of the observable for each precursor on earthquake magnitude
- Explore proposed physical models to explain each earthquake precursor

This report summarizes the results of this research and presents recommendation for follow-up research. With an eye toward future earthquake prediction research, the potential of observing the reported earthquake precursors from a space-based remote-sensing platform is assessed.

2. Selection of earthquake precursors

Two major criteria were used to select the earthquake precursors for this study. The first criterion used for the selection of the earthquake precursory observables was the reported existence of credible scientific evidence for anomalies in the observables prior to at least some earthquakes. As noted above, the successful measurement of some anomalous phenomenon prior to an earthquake usually depends on the luck of having a good scientific experiment operating in an area before, during and after an earthquake. In many cases there have been anecdotal reports of unusual phenomena before earthquakes (e.g., unusual groundwater level changes or unusual animal behavior), but these have not been documented scientifically in a quantitative way. In order to best summarize the behavior of precursory phenomena of interest, we sought out those studies from the published scientific literature that report observations of earthquake precursors that were observed in credible, controlled, calibrated experiments.

The second criterion for the selection of the earthquake precursors is that there are accepted physical models to explain the existence of the precursor. For example, it only makes sense to look for changes in the local electric or magnetic field near an earthquake epicenter if there is some physical or chemical reason why the time prior to the initiation of an earthquake rupture should be accompanied by those field changes. In some cases, there are multiple, competing models to explain the existence of a reported earthquake precursor. We used these competing models as evidence that there is some physical model to explain the precursor, even if there is no current scientific agreement about which model is best.

The earthquake precursors selected for analysis in this study were

- *Electric and magnetic fields* — localized changes in magnetic and electric fields (including changes in ULF, VLF, ELF and RF fields). There is the uncontested observation of a localized strong ULF field change that took place in the area of the 1989 Loma Prieta, California earthquake (magnitude 7.1) during the hours prior to the main shock. A weaker field change was observed about 2 weeks before the main shock.
- *Gas emissions* — there is a great deal of interest in the emissions of various gases from the earth prior to earthquakes. The most well-known experiments have focused on radon gas, but some experiments have measured changes in the emission of other gases from the earth.
- *Water level changes* — wells have been reported to change levels or water quality in the hours, days or weeks prior to a number of earthquakes. In fact, well-water level changes is one of the most commonly reported earthquake precursors.
- *Temperature changes* — there have been some reports of surface temperature changes prior to earthquakes. These may involve changes in the circulation patterns of groundwater bringing water of different temperature to the surface.
- *Surface deformations* — there have been reports that changes in ground elevations over distances of tens of kilometers have preceded

some strong earthquakes. The number of permanent, high quality GPS sites to monitor permanent ground deformations is increasing in earthquake-prone areas, but broadscale remote sensing of surface elevations and especially elevation changes could yield important new clues for predicting earthquakes.

- *Seismicity* — this is already well covered by surface-based seismic instrumentation. However, some high-frequency (acoustic emission) energy and very low frequency seismic motions not detected by conventional seismographs may provide important precursory information. For example, Ihmle and Jordan (1994) have shown that some earthquakes exhibit low frequency precursory signals prior to the higher frequency main rupture.

3. Method of data analysis

For each of the earthquake precursors defined in the previous section, two different research tasks were conducted. The first was to carry out a survey of the scientific literature to find studies documenting anomalous changes in one or more of the selected precursors prior to the occurrence of an earthquake. From these studies, several types of information about the anomalous precursory signal were sought. These included the length of time before the earthquake when the precursor initiated, the duration of the precursor, the amplitude of the precursory signal, the signal-to-noise ratio of the anomalous relative to normal background noise, and the distance from the observation point to the earthquake. In addition, some basic source information was collected for each earthquake, including the date, time, location and magnitude of the earthquake. For each type of precursor, the observational information from the literature survey was collected and analyzed to find the statistical properties of the initiation and duration of the precursors, the strength of the precursory signal, and the relation of the precursory signal properties to the magnitude of the earthquake and the distance from the observation point to the source.

The second research task was to survey the scientific literature for studies proposing physical models to explain each of the precursors. Each physical model was evaluated to see if it predicted pre-earthquake anomalies consistent with the observations collected in the first research task. The goal of this aspect of the research was to find realistic physical models of the precursory earthquake signals that can be used to estimate the strength and character of anomalous pre-earthquake signals for each of the earthquake precursors. In particular, this aspect of the analysis is necessary to determine the importance of such earthquake source properties as magnitude, seismic moment, focal mechanism, depth, and stress drop in generating precursory signals.

4. Summary of the earthquake precursors: observations and models

This section presents a summary of the data collected for each of the precursors analyzed in this study. The reported observations for each precursor for each earthquake are summarized in tables. Discussions of the observations are given in each subsection here. Also described in each subsection are the results of the search for the physical models to explain the earthquake precursor observations. Those models are explored to determine their consistency with the reported precursor observations.

4.1. Electric and magnetic field observations

Anomalous electric and magnetic field prior to earthquakes have been detected by both ground-based and satellite-based instruments. In fact, this is the one earthquake precursor for which satellite-based observations have been reported in the literature. Those satellite observations come from two different studies. The first is a Russian study of an earthquake on March 19, 1979, where Larkina et al. (1989) reported that the Intercosmos 19 satellite detected changes in the ionospheric ELF and VLF emissions at 800 Hz and 4650 Hz from 8 h before to 3 h after each earthquake in their data set. The anomalously large amplitudes at these two frequencies were detected within 2° latitude and 60°longitude of the eventual epicenter of the earthquake.

The second satellite-based EM study of precursory earthquake emissions was reported by Serebryakova et al. (1992). In that study ELF/VLF signals from the COSMOS-1809 satellite were analyzed to look for signals associated with aftershocks of the 1988 earthquake in Armenia. Serebryakova et al. (1992) found that EM radiation at frequencies below 450 Hz was observed during 12 of the 13 orbital passes of the satellite within 6° of longitude of the aftershock epicenter. The anomalously strong emissions were not observed at the latitude of the epicenters of earthquakes but rather 4° to 10° south of those epicenters. The emissions were observed up to a few hours before strong aftershocks took place in the epicentral region. Serebryakova et al. (1992) report that similar anomalous radiation was detected in this same area by the AUREOL-3 satellite.

Finally, Parrot (1994) described a statistical study of ELF/VLF emissions recorded by the AUREOL-3 satellite in the vicinity of the epicenters of 325 earthquakes of Ms > 5 from 1981–1983. In order to maximize the strength of the signals analyzed, Parrot (1994) averaged the data over time, thus sacrificing the time resolution in his study. He reported that the EM signal strength is at a maximum within 10° of longitude of the earthquake epicenters and that these signals are observed at all latitudes. The temporal averaging of the data precluded determining whether the anomalous signals occurred prior to, coincident with, or subsequent to the earthquakes that were analyzed.

There are some important ground-based observations that support the idea that the earth can generate anomalous electric and magnetic signals prior to the occurrences of earthquakes. The most important is that of Fraser-Smith et al. (1990) who, quite by accident, detected a strong ULF magnetic field change near the epicenter of the 17 October 1989 Ms 7.1 Loma Prieta, California earthquake. A low frequency (0.5–2.0 Hz), low amplitude increase in the background ULF field strength began being recorded about a month before the earthquake by an instrument placed at Corralitos (7 km from the eventual epicenter) to monitor ULF background noise for purposes not related to seismology. About 2 weeks before the earthquake, the background ULF signal detected by the instrument increased noticeably. Finally, within a few hours of the earthquake there was an exceptionally great increase in the signal amplitude at frequencies of 0.01 to 0.5 Hz, which grew continuously until the occurrence of the earthquake (and power was lost to the instrument). Atmospheric disturbances as the cause of the anomalous signals were ruled out, and it appears likely that the signals observed were generated by magnetic field changes in the earth below the instrument. Curiously, an ELF/VLF instrument operating about 52 km away on the Stanford U. campus detected no anomalous signals during this same time period.

Also supporting the idea that earthquakes are associated with magnetic and electric field changes in the rock is a study by Kopytenko et al. (1993) who reported unusual ULF signals at a ground-based observatory within 200 km of the epicenter of the 1988 Armenia earthquake. They reported that anomalous ULF emissions were detected several hours before the Armenia main shock and some of its strong aftershocks. This is the same aftershock sequence analyzed by Serebryakova et al. (1992).

As is clear from the discussion here and the results summarized in Table 1, there are still many uncertainties in the observations of possible precursory EM emissions associated with strong earthquakes. Some satellite frequency bands seem to see anomalous signals, while others do not. One study reports the signals at a wide range of latitudes and a narrow range of longitudes, while another sees the opposite pattern. However, all of the data, including the best ground-based observations, show that precursory signals can be observed within several hours of a coming earthquake and that those signals seem to be strongest near the coming epicenter. The Loma Prieta observations suggest that signal-to-noise ratios of anomalous ULF

Table 1
Reported precursory electric and magnetic fields associated with earthquakes.

Earthquake	Magnitude	Date	Type of emission	Before (b)/during (d)/after (a)?	Frequency range	Signal level	Background level	SNR	Distance from epicenter (km)	Instrumentation	Reference
Chile	9.5	5/22/1960	Radio	b (6 days)	18 MHz	2.56×10^{-6} W/Hz			Worldwide	radio astronomy receiver	Warwick et al., 1982
Worldwide (13 events)	5.7–8.3	1964–1973	Geomagnetic	b (<1 h)							Gogatishvili,1984
San Andreas Fault, California	3.9	6/22/1973	Electrical resistivity variation	b (2 months)	DC	10% increase			4 km	Dipole–dipole array	Mazzella and Morrison, 1974
Hollister, California	5.2	11/28/1974	ULF magnetic	b (7 weeks–several months)		0.9–1.5 nT			11 km	Array of 7 proton-precession magnetometers	Smith and Johnston, 1976
Haicheng, China	7.3	2/4/1976	Electric	b (12 h)		−150 mV			20 km		Savage, 1977
Tangshan, China	7.8	7/28/1976	Resistivity	b (2–3 years)		3–5% decrease			≤ 150 km		Zhao and Qian, 1994
Tangshan, China	7.8	7/28/1976	Self potential	b (3 months)		3 mV/km increase			≤ 120 km		Zhao and Qian, 1994
Sungpan–Pingwu, China (3 events)	7.2 6.8 7.2	8/16/1976 8/22/1976 8/23/1976	Telluric currents	b (1 month)		20–50 μA			≤ 200 km		Wallace and Teng, 1980
Worldwide (8 events)	5.0–6.1	1979–1980	VLF EM	b (26–183 min)	0.1–16 kHz				700–14,100 km	Interkosmos–19 satellite	Larkina et al., 1984
Kyoto, Japan	7.0	3/31/1980	VLF electric	b (1/2 h)	81 kHz	+15 dB			250 km	Electric antenna	Gokhberg et al., 1982
Tokyo, Japan	5.3	9/25/1980	VLF electric	b (1 h)	81 kHz	+15–20 dB			55 km	Electric antenna	Gokhberg et al., 1982
Tokyo, Japan	5.0	1/28/1981	VLF electric	b (3/4 h)	81 kHz	+12 dB			50 km	Electric antenna	Gokhberg et al., 1982
Greece (47 events)	3.4–6.8	1983	Electric	b		0.2–15.6 mV			10–160 km		Varotsos and Alexopoulos, 1984
Japan (26 events)	5.0–6.6	1985–1990	VLF electric	b (up to 2 days)	82 kHz				2–895 km	Loop antennas	Yoshino et al., 1993
Kalamata, Greece	6.2	9/13/1986	Electric	b (3–5 days)		10s mV			200 km		Gershenzon and Gokhberg, 1993
Spitak, Armenia	6.9 Ms	12/7/1988	ULF magnetic	b (4 h), a	0.01–1 Hz	0.2 nT	0.02 nT	10	128 km	3-axis high-sensitivity magnetometers	Molchanov et al., 1992
Spitak, Armenia	6.9 Ms	12/7/1988	ULF magnetic	b (4 h), a	0.005–1 Hz	0.1–0.2 nT	0.03 nT	6.67	120 km and 200 km		Kopytenko et al., 1993
Ito, Japan (earthquake swarm)	≤5.5	June–July 1989	ELF/VLF electric	b (4–6 h)	1–9 kHz	~10 mV			200 km	Borehole electrodes	Fujinawa and Takahashi, 1990
Loma Prieta, California	7.1 Ms	11/19/1989	ELF/VLF EM	b (3 h), d	0.01 Hz	5–60 nT $Hz^{-1/2}$	~1 nT $Hz^{-1/2}$		52 km	Ground-based magnetometers	Fraser-Smith et al., 1990
Loma Prieta, California	7.1 Ms	11/18/1989	ULF magnetic	b (3 h), a	0.01 Hz	4–5 nT			7 km		Molchanov et al., 1992
Loma Prieta, California	7.1 Ms	11/18/1989	ULF magnetic	a	0.01–10 Hz	1 nT			7.3 km	Proton magnetometers	Mueller and Johnston, 1990
Armenia region		1989	ELF/VLF EM	b (3 h)	140 Hz	10 mγ			6 in. long, 2–4 in latitude	COSMOS-1809 satellite	Serebryakova et al., 1992
Armenia region		1990	ELF/VLF EM	b (3 h)	450 Hz	3 mγ			6 in long, 2–4 in latitude	COSMOS-1809 satellite	Serebryakova et al., 1992
Worldwide (325 eq's)	Ms>5		ELF/VLF EM	b (0–4 h)	140 Hz	3.28E−5 γ $Hz^{-1/2}$	1.53E−5 γ $Hz^{-1/2}$	2.14	Δlong<10	ARCAD-3 aboard AUREOL-3 satellite	Parrot, 1994
Worldwide (325 eq's)	Ms>5		ELF/VLF EM	b (0–4 h)	800 Hz	9.08E−5 γ $Hz^{-1/2}$	1.57E−5 γ $Hz^{-1/2}$	5.78	Δlong<10	ARCAD-3 aboard AUREOL-3 satellite	Parrot, 1994
Worldwide (325 eq's)	M>5.5		LF radio wave			10^2–10^3 V m^{-1}			60 in long, 2 in latitude	Intercosmos-19 satellite	Parrot, 1994
Upland, California	4.7	4/17/1990	ELF magnetic	b (1 day)	3.0–4.0 Hz	−40 dB	−46.8 dB		160 km	Vertical magnetic sensor	Dea et al., 1993
Western Iran	7.5	6/20/1990	Ionospheric (radio wave)	b (16 days)	0–8 kHz, 10–14 kHz, F region				250–2000 km	Intercosmos-24 satellite	Shalimov and Gokhberg, 1998

Watsonville, California	4.3	3/23/1991	ELF magnetic	b (data averaged over 2 days)	3.0–4.0 Hz	−43 dB	−47.6 dB		600 km	North–south magnetic sensor	Dea et al., 1993
Watsonville, California	4.3	3/23/1991	ELF magnetic	b (data averaged over 2 days)	3.0–4.0 Hz	−44 dB	−46.8 dB		600 km	Vertical magnetic sensor	Dea et al., 1993
Coalinga, California	4.0	1/15/1992	ELF magnetic	b (data averaged over 2 days)	3.0–4.0 Hz	−50 dB	−57 dB		400 km	Vertical magnetic sensor	Dea et al., 1993
Central Italy	3.0–4.3	1991–1994	LF radio waves	b (6–10 days)	216 kHz	−21 to −22 db (atmospheric) −7 to −5 db (ground)			<100 km		Bella et al., 1998
Hokkaido, Japan	7.8	7/12/1993	foF_2 ionospheric	b (3 days)					290 km, 780 km, 1280 km (3 stations)		Ondoh, 1998
Guam	Ms 7.1	8/8/1993	ULF magnetic	b (1 month)	0.02–0.05 Hz	0.1 nT			65 km	3-axis ring–core-type fluxgate magnetometer	Hayakawa et al., 1996; Hayakawa et al., 1999
Mexico (Pacific Coast)	$M \geq 6.0$ (4 events)	1993–1994	ULF electric		0–0.125 Hz				< 200 km		Yépez et al., 1995
Hokkaido–Toho–Oki, Japan	M_W 8.1	10/4/1994	VLF electric	b (20 min)	1–9 kHz	1.34 mV			> 1000 km	Borehole antenna	Fujinawa and Takahashi, 1998
Taiwan	$M \geq 6.0$ (14 events)	1994–1999	ULF magnetic	b (1–6 days)					<400 km	IPS-42 ionosonde	Liu et al., 2000
Hyogo-ken Nanbu (Kobe), Japan	7.2	1/17/1995	DC geopotential, ELF magnetic, VLF radio, MF–HF, VHF FM-wave	b (up to 7 days)	223 z, 1–20 kHz, 163 kHz, 77.1 MHz				≥ 100 km		Enomoto et al., 1998
Hyogo-ken Nanbu (Kobe), Japan	7.2	1/17/1995	VLF radio	b (2 days)	10.2 kHz				70 km		Molchanov et al., 1998
Hyogo-ken Nanbu (Kobe), Japan	7.2	1/17/1995	Electric	b (1 h)	22.2 MHz	0.2 W signal power			77 km	Phase-switched interferometer with two horizontally-polarized antennas	Maeda and Tokimasa, 1996
Kozani-Grevena, Greece	6.6	5/13/1995	VHF electromagnetic	b (20 h)	*E*: 41 and 5 MHz *M*: 3 & and 10 kHz	~300 mV above background			Δlat, Δlong <3	Electric dipole antennas, magnetic loop antennas	Eftaxias et al., 2002
Kozani-Grevena, Greece	6.6	5/13/1995	Electric, magnetic	b (2 weeks)		10–60 mV/km, 0.4 nT			70 m, 200 km		Bernard et al., 1997
Biak, Indonesia	8.2	2/17/1996	UHF magnetic	b (1–1.5 months)	5–30 mHz	0.2–0.3 nT			≤ 1200 km	Fluxgate magnetometers	
Chiba-ken Toko-oki, Japan	6.2	9/11/1996	VHF electric	b (3 days)					320, 430 km	Vertical-dipole ground electrodes	Enomoto et al., 1997
Akita-ken Nairiku-Nanbu, Japan	5.9	8/11/1996	VHF electric	b (6 days)					<100 km	Vertical-dipole ground electrodes	Enomoto et al., 1997
Vrancea, Romania	*M* (3.9 (19 events)	1997–1998	ULF electromagnetic	b (1–12 days)	3 kHz		~15 pT $Hz^{-1/2}$		100 km	3-axis fluxgate magnetometers, non-polarizable electric sensors	Enescu et al., 1999
Umbria–Marche, Italy	5.5	3/26/1998	LF radio	b (1.5 months)	0.006 Hz	6–8 dB increase			818 km	Radio wave vertical antenna	Biagi et al., 2001
San Juan Bautista, California	MW 5.1	8/12/1998	UHF magnetic	b (2 h)	0.01–10 Hz	0.02 nT			3 km	3-component magnetic field inductor coils	Karakelian et al., 2002
Athens, Greece	5.9	9/7/1999	VHF electromagnetic	b (12–17 h)	*E*: 41 and 5 MHz *M*: 3 and 10 kHz	(300 mV above background)		6	Δlat, Δlong <3	Electric dipole antennas, magnetic loop antennas	Eftaxias et al., 2001a,b
Chi-Chi, Taiwan	7.7	9/20/1999	ULF magnetic	b (1, 3, 4 days) 3 signals					< 400 km	IPS-42 ionosonde	Liu et al., 2000
Chi-Chi, Taiwan	M_W 7.6	9/20/1999	foF_2 ionospheric	b (3–4 days)					120 km	IPS-42 ionosonde	Chuo et al., 2002
Chia-Yii, Taiwan	M_W 6.4	10/22/1999	foF_2 ionospheric	b (1–3 days)					179 km	IPS-42 ionosonde	Chuo et al., 2002
Japan	*M* (4.8 (29 events)	9/4/2001–4/8/2003	VHF electromagnetic	b (up to 5 days)					Δlat Δlong <4	Two 5-element Yagi antennas	Fujiwara et al., 2004

fields associated with coming earthquakes can be quite strong (up to 60). The three satellite-based studies described above report signal-to-noise ratios up to 10. Thus, EM radiation significantly above the background noise prior to at least some earthquakes may be observable from space in carefully designed experiments.

4.2. Electric and magnetic field models

Several physical models have been proposed to explain the observed electromagnetic precursors associated with earthquakes. These models can be classified into two main categories, which can be related to the frequency of the resultant electromagnetic precursor. The first class of models attempts to explain the observation of magnetic fields in the ULF range. The second class of models relates to electric fields observed at higher frequency, principally in the ELF/VLF range, but also extending to the LF and HF frequency bands.

4.3. ULF magnetic fields

For ULF magnetic fields, there have been three mechanisms proposed to explain the generation of these precursory signals. The first of these mechanisms is the magnetohydrodynamic (MHD) effect (e.g., Draganov et al., 1991). For this mechanism, the flow of an electrically conducting fluid in the presence of a magnetic field generates a secondary induced field. The MHD equation is derived from Maxwell's equations and is given by

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times \mathbf{v} \times \mathbf{B} + \frac{\nabla^2 \mathbf{B}}{\mu_0 \sigma}, \tag{1}$$

where μ_0 is the permeability of free space, s is the conductivity, $\mathbf{v}$ is the fluid velocity, and $\mathbf{B}$ is the magnetic field. The first term on the right is the convection of the magnetic field caused by the resistance to flux changes in the conductive loop. The second term represents the diffusion of the magnetic field caused by ohmic dissipation.

From the two terms on the right-hand side of the MHD equation, a magnetic Reynolds number R_m, analogous to the hydrodynamic Reynolds number, can be defined. The Reynolds number defines the relative importance of the convective and diffusive terms. Using dimensional analysis,

$$R_m = \frac{|\nabla \times \mathbf{v} \times \mathbf{B}|}{|\lambda \nabla^2 \mathbf{B}|} = \mu_0 \sigma v \ell, \tag{2}$$

where $\lambda = 1/\mu_0\sigma$ and ℓ is the characteristic length of the source. Then the induced magnetic field $\mathbf{B}_i$ is given by

$$\mathbf{B}_i = R_m \mathbf{B}. \tag{3}$$

The second mechanism proposed for the generation of precursory ULF magnetic fields is the piezomagnetic effect (e.g., Sasai, 1991). For this mechanism, a secondary magnetic field is induced due to a change in magnetization in ferromagnetic rocks in response to an applied stress. For an isotropic material, the change in magnetization ΔM_i due to the piezomagnetic effect is given by

$$\Delta M_i = \left(-\frac{1}{2}\tau_{kk}\delta_{ij} + \frac{3}{2}\tau_{ij}\right)\beta M_j, \tag{4}$$

where β is the stress sensitivity, τ is the stress tensor, and δ_{ij} is the Kronecker delta. If the material is linear elastic and obeys Hooke's law, the constitutive relation can be written as

$$\tau_{ij} = \lambda \delta_{ij} \nabla \cdot \mathbf{u} + \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right), \tag{5}$$

where λ and μ are the Lamé constants and $\mathbf{u}$ is the displacement vector. Substituting this constitutive law into the into the equation for the change in magnetization leads to a difference equation that can be numerically integrated to determine the magnetic field at the surface resulting from piezomagnetic effects.

The third mechanism proposed to explain the generation of ULF magnetic fields is the electrokinetic effect (Nourbehecht, 1963; Fitterman, 1978, 1979). The electrokinetic effect results from the flow of electric currents in the earth in the presence of an electrified interface at solid–liquid boundaries. These electric currents in turn produce magnetic fields. The current density and fluid velocity are coupled processes defined by

$$\mathbf{j} = -\sigma \nabla E - \frac{\varepsilon \varsigma}{\eta} \nabla P, \tag{6}$$

and

$$\mathbf{v} = -\frac{\varepsilon \varsigma}{\eta} \nabla E - \frac{k}{\eta} \nabla P, \tag{7}$$

where $\mathbf{j}$ is the current density, $\mathbf{v}$ is the fluid velocity, E is the streaming potential, ε is the dielectric constant, ς is the zeta potential (a measure of the initial potential at the electrified interface), σ is the fluid conductivity, η is the dynamic viscosity, k is the permeability, and P is the fluid pressure. The magnetic field $\mathbf{B}$ is induced by the flow of electric current and is given by the Biot–Savart law

$$\mathbf{B} = \frac{\mu_0}{4\pi} \int_V \int \int \frac{\nabla' \times \mathbf{j}(\mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|} dV, \tag{8}$$

where μ_0 is the permeability of free space.

Fenoglio et al. (1994a,b; 1995) analyzed the relative contribution of these three mechanisms applied to the ULF magnetic field signals observed prior to the 17 October 1989 Loma Prieta earthquake (Fraser-Smith et al., 1990). The analysis focused on two major increases in the magnetic field prior to the earthquake, the first having a magnitude of 2.0 nT occurring on 5 October 1989 and the second of magnitude 6.7 nT occurring just 3 h prior to the earthquake.

The results of these studies indicate that the MHD effect has a negligible contribution to the ULF magnetic signal, due to the rapid attenuation of the magnetic field strength, which decays as $1/r^3$. The piezomagnetic effect contributes an induced magnetic field of at most 10^{-2} nT, approximately two orders of magnitude less than the observed signals. The electrokinetic effect appears to be the most significant, contributing an induced magnetic field of about 5–10 nT, of about the same order as the observed fields prior to the earthquake.

In contrast, Draganov et al. (1991) attributed the observed precursory ULF magnetic fields as being the result of magnetohydrodynamic effects. However, as pointed out by Fenoglio et al. (1995), the Draganov analysis used certain model parameters that were unrealistic. These include a value for the permeability k of 10^{12} m^2, a value which is approximately two orders of magnitude higher than would be expected for the rocks in the earthquake source region, and a pressure field of 4×10^{10} Pa, well above the lithostatic pressure at that depth (about 10^8 Pa).

4.4. ELF/VLF/LF/HF electric fields

As mentioned above, there have been several reports in the literature of anomalous electric fields in the ELF/VLF frequency ranges and higher. The mechanisms proposed for the generation of these fields include contact electrification, separation electrification, and piezoelectrification (Ogawa et al., 1985) and atmospheric electricity generated by the emission of radon gas from the earth (Pierce, 1976).

Ogawa et al. (1985) examined the electric field generated from granite samples that were struck with a hammer or fractured by bending. They attributed the generation of the electric field to two possible mechanisms: contact (or separation) electrification or piezoelectrification. These mechanisms create a dipole moment due to separation

Table 2
Reported precursory gas emissions associated with earthquakes.

Area (notes)	Country	Date	z [km]	Gas		δa [%]	Background level [cpm]	Signal level [cpm]	M	D [km]	d [days]	δt [days]	References
Southern (a)	Iceland	7/3/1978		Rn	+	380	Not given	Not given	2.7	14	22	25	Hauksson and Goddard, 1981
Iceland	Iceland	8/28/1978		Rn	+	60	Not given	Not given	3.4	5	17	30	Hauksson and Goddard, 1981
Seismic	Iceland	8/28/1978		Rn	+	280	Not given	Not given	3.4	21	17	27	Hauksson and Goddard, 1981
Seismic	Iceland	11/19/1978		Rn	−	80	Not given	Not given	4.3	16	18	10	Hauksson and Goddard, 1981
Seismic	Iceland	6/29/1979		Rn	+	40	Not given	Not given	1.9	9	19	25	Hauksson and Goddard, 1981
Seismic	Iceland	9/5/1979		Rn	+	40	Not given	Not given	2.8	8	17	20	Hauksson and Goddard, 1981
Seismic	Iceland	9/5/1979		Rn	+	100	Not given	Not given	2.8	5	33	33	Hauksson and Goddard, 1981
Tjörnes Facture Zone	Iceland	12/15/1979		Rn	+	100	Not given	Not given	4.1	56	50	50	Hauksson and Goddard, 1981
Tjörnes Facture Zone	Iceland	9/16/2002		Cu	+		0.91 ± 0.37 ppb	6.28 ($2\sigma = 2.54$)	5.8	100		1 week	Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		Zn	+		26 ± 23 ppb	381 ppb ($2\sigma = 134$)	5.8	100		2 weeks	Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		Mn	+		1.25 ± 0.35 ppb	6.76 ppb ($2\sigma = 2.91$)	5.8	100		5 weeks	Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		Cr	+		2.8 ± 2.2 ppb	34 ppb ($2\sigma = 16$)	5.8	100		10 weeks	Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		Fe	+		2.8 ± 2.2 ppb	28 ($2\sigma = 14.8$)	5.8	100		10 weeks	Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		Na/Ca	+				5.8	100			Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		B, Ca, K, Li, Mo, Na, Rb, S, Si, Sr Cl, SO_4	+	12–19%			5.8	100			Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		$\delta^{18}O$	−	1.0 ± 0.1%			5.8	100			Claesson et al., 2004
Tjörnes Facture Zone	Iceland	9/16/2002		δD	−	9 ± 1%			5.8	100			Claesson et al., 2004
San Andreas fault	USA	3/17/1976	9	Rn	+	120	Not given	Not given	4.3	25	60	25	King, 1978; King, 1980
San Andreas fault	USA	1/19/1977	6	Rn	+	500	Not given	Not given	4	47	90	25	King, 1978; King, 1980
San Andreas fault	USA	12/15/1977	11	Rn	+	400	Not given	Not given	4	45	15	30	King, 1980
San Andreas fault	USA	8/29/1978	6	Rn	+	200	Not given	Not given	4.2	75	240	90	King, 1980
South California	USA	9/24/1977	15	Rn	+	44	Not given	Not given	2.9	21	1	5	Shapiro et al., 1980
South California	USA	12/20/1977	6	Rn	+	40	Not given	Not given	2.8	12	10	24	Shapiro et al., 1980
Malibu	USA	1/1/1979	?	Rn		4 spikes	Not given	Not given	4.6	54	4 spikes		Shapiro et al., 1980
Coalinga fault (b)	USA	6/7/1909		H_2	+	800	Not given	Not given	5.2 to 6.7	40–120			Sato et al., 1986
Kettleman Hill	USA	4/8/1985		Rn	+	100	Not given	Not given	5.6	300	10	7	Teng and Sun, 1986
Raquette Lake	USA			Rn			Not given	Not given	3.9	14			Fleischer, 1981
Blue Mountain Lake	USA			Rn			Not given	Not given	1.5	1			Fleischer, 1981
Pearblossom	USA	11/22/1976		Rn	+	36	Not given	Not given	3.5	25	31		Hauksson, 1981
Jocasse	USA	2/23/1977		Rn	−	50	Not given	Not given	2.3	1	14		Hauksson, 1981
Pasadena	USA	9/24/1977		Rn	+	62	Not given	Not given	2.9	21	3	5	Shapiro et al., 1980
Pasadena	USA	12/20/1977		Rn	+	25	Not given	Not given	2.8	12	9		Shapiro et al., 1980
Malibu	USA	1/1/1979		Rn	+	72	Not given	Not given	4.7	54	42		Shapiro et al., 1980
Malibu	USA	1/1/1979		Rn	+	225	Not given	Not given	4.7	20	82		Hauksson, 1981
Big Bear	USA	6/28/1979		Rn	+	310	Not given	Not given	5	85	12		Hauksson, 1981
Big Bear	USA	6/28/1979		Rn	+	72	Not given	Not given	5	31	45		Hauksson, 1981
Imperial Valley	USA	10/15/1979		Rn	+	400	Not given	Not given	6.6	335	116		Hauksson, 1981
Imperial Valley	USA	10/15/1979		Rn	+	200	Not given	Not given	6.6	310	95		Hauksson, 1981
Imperial Valley	USA	10/15/1979		Rn	+	72	Not given	Not given	6.6	265	145		Hauksson, 1981
Imperial Valley	USA	10/15/1979		Rn	+	64	Not given	Not given	6.6	260	2		Hauksson, 1981
Imperial Valley	USA	10/15/1979		Rn			Not given	Not given	6.6	300			Fleischer, 1981
Caruthersville, Missouri	USA	6/??/1979		Rn	+	375	not given	Not given	3.9	nd	33	60	Steele, 1981
Caruthersville, Missouri	USA	8/??/1981		Rn	+	340–504			4.0	40	5 months	2–7 months	Steele, 1984
Central Arkansas (earthquake swarm)	USA	1/??/1982		Rn	−				4.0–4.5	160	1 year	1 year	Steele, 1984
SW Illinois	USA	5/15/1983		Rn	+	483			4.2	120–320	2 months		Steele, 1984
New Madrid Seismic Zone	USA	1/28/1983		Rn	+	400			3.5	50	2 months		Steele, 1984
Big Bear, California	USA	6/30/1979		Rn	+	60	Not given	Not given	4.8	30	150	120	Chung, 1985
	USA			He	+	65	Not given	Not given	4.8	30	150	120	Chung, 1985
Alandale, California	USA	6/??/1983		Rn	+	1200	not given	Not given	3.7	13	3	15	Shapiro et al., 1985

(continued on next page)

Table 2 (*continued*)

Area (notes)	Country	Date	z [km]	Gas		δa [%]	Background level [cpm]	Signal level [cpm]	M	D [km]	d [days]	δt [days]	References
San Andreas, California	USA	10/13/1979		Rn	+	400	Not given	Not given	3.4	40	0.5	0.2	King, 1985
	USA	12/22/1979		Rn	+	800	Not given	Not given	3.3	20	1	0.5	King, 1985
Loma Prieta, California	USA	10/17/1989		He	+	4	Not given	Not given	7.1	60		1	Reimer, 1990
Coyote Lake, California	USA	8/6/1979		He	−		Not given	Not given	5.9	65		21	Reimer, 1990
Mt Diablo, California	USA	1/24/1980		He	−		Not given	Not given	5.5	155		35	Reimer, 1990
Salinas, California	USA	4/13/1980		He	−		Not given	Not given	4.9	35		28	Reimer, 1990
Livermore, California	USA	8/24/1980		He	+		Not given	Not given	4.1	120			Reimer, 1990
San Juan Bautista, California	USA	1/7/1981		He	−		Not given	Not given	4.5	45		10	Reimer, 1990
San Juan Bautista, California	USA	4/13/1980		D	−	7‰			4.8			1 month	O'Neil and King, 1980
Hollister, California (5 events)	USA	1979–1980		He	−				≥4.0			5–6 weeks	Reimer, 1980
Big Bear, California (swarm) (c)	USA	July 1979		Rn	+	72			4.8			60 ± 15	Craig, 1980
Big Bear, California (swarm) (c)	USA	July 1979		He	+	72			4.8			60 ± 15	Craig, 1980
Big Bear, California (swarm) (c)	USA	July 1979		CH_4	+	60			4.8			60 ± 15	Craig, 1980
Big Bear, California (swarm) (c)	USA	July 1979		Ar	+	25			4.8			60 ± 15	Craig, 1980
Big Bear, California (swarm) (c)	USA	July 1979		N_2	+	17			4.8			60 ± 15	Craig, 1980
Sand Point, Alaska	USA	2/14/1983		Rn	+	6–40 times background			6.3	180		6 weeks	Fleischer and Mogro-Campero, 1985
Mexico	Mexico	9/19/1985		Rn	+	200	Not given	Not given	8.1	260	nd	nd	Segovia et al., 1989
Reventador (d)	Ecuador	3/6/1987	14	Rn			Not given	Not given	6.9	367		50	Flores Humanante et al., 1990
	Ecuador				+	230	Not given	Not given	6.9	377		15–50	Flores Humanante et al., 1990
	Ecuador				+	400	Not given	Not given	6.9	339		15–35	Flores Humanante et al., 1990
	Ecuador				+	100	Not given	Not given	6.9	388		50	Flores Humanante et al., 1990
	Ecuador				+	100	Not given	Not given	6.9	183		15–40	Flores Humanante et al., 1990
	Ecuador				+	300	Not given	Not given	6.9	350		15–40	Flores Humanante et al., 1990
Ligurian Sea	France	5/1/1986		Rn	+	100	Not given	Not given	3.9	56	5	3	Borchiellini et al., 1991
Western Nagano	Japan	9/14/1984		N_2/Ar	−		Not given	Not given	6.8	50	230	120	Sugisaki and Sugiura, 1985, 1986
	Japan			He/Ar	−		Not given	Not given	6.8	50	230	120	Sugisaki and Sugiura, 1985, 1986
	Japan			CH_4/Ar	−		Not given	Not given	6.8	50	230	120	Sugisaki and Sugiura, 1985, 1986
Western Nagano	Japan	9/14/1984		H_2	−		Not given	Not given	6.8	50	120	50	Sugisaki and Sugiura, 1985, 1986
	Japan			H_2	+	2000	Not given	Not given	6.8	70		15	Sugisaki and Sugiura, 1985, 1986
?	Japan	8/6/1982		H_2			Not given	Not given	3.8	8.6		70	Sugisaki and Sugiura, 1985, 1986
Byakko	Japan	9/24/1990		He/Ar	+		Not given	Not given	6.6	280	0.1	coseismic	Nagamine and Sugisaki, 1991a
	Japan	10/16/1990		He/Ar	+		Not given	Not given	4.2	31	0.15	coseismic	Nagamine and Sugisaki, 1991a
	Japan	5/11/1991		He/Ar	+		Not given	Not given	3.9	35	0.25	coseismic	Nagamine and Sugisaki, 1991a
Chiba-Ken-Oki	Japan	6/1/1990		Rn	−	3	Not given	Not given	6	200	1		Wakita et al., 1989
Nagoya	Japan	4/3/1977		He/Ar	+		Not given	Not given	4.1	100	60	60	Sugisaki, 1978
	Japan	8/6/1977		He/Ar	+		Not given	Not given	4.3	15	60	50	Sugisaki, 1978
	Japan	8/15/1977		He/Ar	+		Not given	Not given	4.3	45	75	50	Sugisaki, 1978
	Japan	1/14/1978		He/Ar	+		Not given	Not given	7	216	130	120	Sugisaki, 1978
Izu–Oshima	Japan	1/14/1978		Rn	+	7	Not given	Not given	6.8	25	230		Wakita et al., 1988
Izu–Oshima	Japan	1/14/1978		Rn	−	8	Not given	Not given	6.8	25	7		Wakita et al., 1988
?	Japan	5/26/1983		H_2	+	100,000	Not given	Not given	7.7	480	?	?	Satake et al., 1985
Matsuyama area	Japan	12/10/1982		CH_4/Ar	+	120	Not given	Not given	4.9	50	120	100	Kawabe, 1984
Subducted zone	Japan	3/6/1984		Rn			Not given	Not given	7.9	1000	2	9	Igarashi and Wakita, 1990
	Japan	2/6/1987		Rn			Not given	Not given	6.7	130	4	3	Igarashi and Wakita, 1990
Kobe (e)	Japan	1/17/1995		Rn	+	200	Not given	Not given	7.2	30	90	75	Igarashi et al., 1995
	Japan	1/17/1995		Rn	+	1000	Not given	Not given	7.2	30	3	10	Igarashi et al., 1995
Pohai Bay	PR China	6/18/1969		Rn	+	60	Not given	Not given	7.4	170	170		Hauksson, 1981
Ningshin	PR China	8/5/1971		Rn	+	200	Not given	Not given	4.3	42	40		Hauksson, 1981
Hsingtang	PR China	6/6/1974		Rn	+	290	Not given	Not given	4.9	18	16		Hauksson, 1981
Haicheng	PR China	2/4/1975		Rn	+	38	Not given	Not given	7.3	50	270		Hauksson, 1981
Haicheng	PR China	2/4/1975		Rn	+	17	Not given	Not given	7.3	50	50		Hauksson, 1981
Haicheng	PR China	2/4/1975		Rn	−	43	Not given	Not given	7.3	140	66		Hauksson, 1981
Haicheng	PR China	2/4/1975		Rn	+	20	Not given	Not given	7.3	140	8		Hauksson, 1981
Haicheng	PR China	2/4/1975		Rn			Not given	Not given	7.3	26			Fleischer, 1980
	PR China						not given	Not given		14			Fleischer, 1981
Liaoyang	PR China						Not given	Not given	4.8	32			Fleischer, 1981

Tangshan	PR China	6/27/1976	Rn	+	15	Not given	Not given	7.8	50	970		Hauksson, 1981
Tangshan	PR China	6/27/1976	Rn	+	50	Not given	Not given	7.8	100	15		Hauksson, 1981
Tangshan	PR China	6/27/1976	Rn	−	40	Not given	Not given	7.8	130	1370		Hauksson, 1981
Tangshan	PR China	6/27/1976	Rn	+	27	Not given	Not given	7.8	130	162		Hauksson, 1981
Tangshan	PR China	6/27/1976	Rn			Not given	Not given	7.8	1800			Fleischer, 1981
Chienan	PR China	3/7/1977	Rn	+	70	Not given	Not given	6	200	3	1	Teng, 1980
Sabteh	PR China	4/8/1972	Rn	+	55	Not given	Not given	5.2	70	12		Teng, 1980
Takung	PR China	9/27/1972	Rn	+	34	Not given	Not given	5.8	54	12		Teng, 1980
Luhuo	PR China	2/6/1973	Rn	+	120	Not given	Not given	7.9	200	9		Wakita et al., 1988
Yiliang	PR China	4/22/1973	Rn	+	41	Not given	Not given	5.2	340	14		Teng, 1980
Songpan	PR China	5/8/1973	Rn	+	40	Not given	Not given	5.2	345	14		Hauksson, 1981
Mapien	PR China	6/29/1973	Rn	+	89	Not given	Not given	5.5	200	9		Wakita et al., 1988
Lungling	PR China	5/29/1976	Rn	+	20	Not given	Not given	7.5	20	510		Hauksson, 1981
Lungling	PR China	5/29/1976	Rn	+	15	Not given	Not given	7.5	190	425		Hauksson, 1981
Lungling	PR China	5/29/1976	Rn	+	8	Not given	Not given	7.5	210	160		Hauksson, 1981
Lungling	PR China	5/29/1976	Rn	+	12	Not given	Not given	7.5	215	130		Hauksson, 1981
Lungling	PR China	5/29/1976	Rn	+	7	Not given	Not given	7.5	360	75		Hauksson, 1981
Lungling	PR China	5/29/1976	Rn	+	20	Not given	Not given	7.5	420	290		Hauksson, 1981
Lungling	PR China	5/29/1976	Rn	+	200	Not given	Not given	7.5	450	12		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	29	Not given	Not given	7.2	40	480		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	11	Not given	Not given	7.2	100	420		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	20	Not given	Not given	7.2	100	190		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	70	Not given	Not given	7.2	320	1		Teng, 1980
Songpan-Pingwu	PR China	8/16/1976	Rn	−	12	Not given	Not given	7.2	320	200		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	90	Not given	Not given	7.2	340	48		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	−	60	Not given	Not given	7.2	340	160		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	55	Not given	Not given	7.2	390	160		Hauksson, 1981
Songpan-Pingwu	PR China	8/16/1976	Rn	+	110	Not given	Not given	7.2	560	34		Hauksson, 1981
Fengzhen	PR China	??/??/81	H_2	+	1000	Not given	Not given	5.8	285	15	7	Shi and Cai, 1986
Tangshan	PR China	7/27/1976	Rn	+	50	Not given	Not given	7.8	460	8	10	Shi and Cai, 1986
Ninghe	PR China	11/15/1976	H_2	+	900	Not given	Not given	6.9	nd	12	8	Jiang et al., 1981
Songpan	PR China	8/16/1976	Rn	+	100	Not given	Not given	7.2	350	1.5	10	Jiang and Li, 1981
Haicheng	PR China	1975	F−					7.4				Liang, 1980
Tangshan	PR China	1976	F−					7.8				Liang, 1980
Songpan-Pingwu	PR China	1976	F−					7.9				Liang, 1980
Ninghe	PR China	1977	F−					6.5				Liang, 1980
Taschkent	Ex-USSR	4/26/1966	Rn	+	20	Not given	Not given	5.3	5	400		Hauksson, 1981
Taschkent	Ex-USSR	3/24/1967	Rn	+	100	Not given	Not given	4	5	11		Hauksson, 1981
Taschkent	Ex-USSR	6/20/1967	Rn	+	23	Not given	Not given	3.5	5	3		Hauksson, 1981
Taschkent	Ex-USSR	7/22/1967	Rn	+	20	Not given	Not given	3.5	5	3		Hauksson, 1981
Taschkent	Ex-USSR	11/9/1967	Rn	+	23	Not given	Not given	3	5	8		Hauksson, 1981
Taschkent	Ex-USSR	11/17/1967	Rn	+	23	Not given	Not given	3.3	5	7		Hauksson, 1981
Taschkent	Ex-USSR	12/17/1967	Rn	+	23	Not given	Not given	3	5	4		Hauksson, 1981
Uzbekistan	Ex-USSR	2/13/1973	Rn	+	47	Not given	Not given	4.7	130	5		Hauksson, 1981
Markansu	Ex-USSR	8/11/1974	Rn	+	100	Not given	Not given	7.3	530	100		Hauksson, 1981
Tien Shan	Ex-USSR	2/12/1975	Rn	+	10	Not given	Not given	5.3	100	110		Hauksson, 1981
Gazli	Ex-USSR	5/17/1976	Rn	+	220	Not given	Not given	7.3	470	4		Hauksson, 1981
Gazli	Ex-USSR	5/17/1976	Rn	+	25	Not given	Not given	7.3	550	90		Hauksson, 1981
	Ex-USSR		Rn			not given	Not given	7	700			Fleischer, 1981
Gazli	Ex-USSR	5/17/1976	Rn			Not given	Not given	7.3	400			Fleischer, 1981
Isfarin-Batnen	Ex-USSR	1/31/1977	Rn	−	30	Not given	Not given	6.6	190	60		Hauksson, Fleischer, 1981
Isfarin-Batnen	Ex-USSR	1/31/1977	Rn	−	20	Not given	Not given	6.6	200	125		Hauksson, 1981
Alma-Ata	Ex-USSR	3/24/1978	Rn	+	32	Not given	Not given	7.1	65	50		Hauksson, 1981
Zaalai	Ex-USSR	11/1/1978	Rn	−	30	Not given	Not given	6.7	270	470		Hauksson, 1981
Zaalai	Ex-USSR	11/1/1978	Rn	−	40	Not given	Not given	6.7	300	470		Hauksson, 1981
Zaalai	Ex-USSR	11/1/1978	Rn	+	20	Not given	Not given	6.7	150	75		Hauksson, 1981
Zaalai	Ex-USSR	11/1/1978	Rn	−	20	Not given	Not given	6.7	150	70		Hauksson, 1981
Iran	Ex-USSR	9/16/1978	H_2S	+	170	Not given	Not given	?	nd	2	25	Barsukov et al., 1985
Duchambe	Ex-USSR	9/29/1981	Hg_{gas}	+	400	Not given	Not given	?	20		1.2	Varshal et al., 1985

(continued on next page)

Table 2 (*continued*)

Area (notes)	Country	Date	z [km]	Gas		δa [%]	Background level [cpm]	Signal level [cpm]	M	D [km]	d [days]	δt [days]	References
	Ex-USSR				+	9000	Not given	Not given	?			0.8	Varshal et al., 1985
Paravani, Caucasus	USSR	5/13/1986							5.6				Bella et al., 1995a,b
Spitak, Caucasus	USSR	12/7/1988							6.9				Bella et al., 1995a,b
Kamchatka Peninsula	Russia	3/2/1992	34	Na^+, Ca^{2+}, HCO_3,SO_4^{2}	+	Exceeds 3σ level				100		35	Biagi et al., 2000a,b
				Ca^{2+}	+								
				HCO_3^-	−								
				SO_4^{2-}	+								
Kamchatka Peninsula	Russia	11/13/1993	56	Na^+, Ca^{2+}, HCO_3,SO_4^{2}	+	Exceeds 3σ level				152		6–80	Biagi et al., 2000a,b
				Ca^{2+}	+								
				HCO_3^-	−								
				SO_4^{2-}	+								
Kamchatka Peninsula	Russia	1/1/1996	10	Na^+, Ca^{2+}, $HCO_3SO_4^{2}$	+	Exceeds 3σ level				96		107	Biagi et al., 2000a,b
				Ca^{2+}	+								
				HCO_3^-	−								
				SO_4^{2-}	+								
Kamchatka Peninsula	Russia	6/21/1996	1	Na^+, Ca^{2+}, HCO_3,SO_4^{2}	+	Exceeds 3σ level				228		72	Biagi et al., 2000a,b
				Ca^{2+}	+								
				HCO_3^-	−								
				SO_4^{2-}	+								
Kamchatka Peninsula	Russia	12/5/1997	10	Ar	+	Exceeds 3σ level				366		6–80	Biagi et al., 2000a,b
				N_2	+								
Irpinia	Italy	11/23/1980		Rn	+	25	Not given	Not given	6.5	220	150	150	Allegri et al., 1983
Irpinia	Italy	11/23/1980		Rn	+	170	Not given	Not given	6.5	200	180	180	Allegri et al., 1983
Northern Taiwan	Taiwan	10/18/1980	8.2	Rn	nd		Not given	Not given	5.8	39	nd	19	Liu et al., 1985
	Taiwan	5/14/1981	8.2	Rn	nd		Not given	Not given	5.2	23	nd	11	Liu et al., 1985
	Taiwan	6/21/1981	8.4	Rn	nd		Not given	Not given	4.6	14	nd	15	Liu et al., 1985
	Taiwan	7/18/1981	6.7	Rn	nd		Not given	Not given	5	37	nd	4	Liu et al., 1985
	Taiwan	10/31/1982	9.8	Rn	nd		Not given	Not given	5.3	45	nd	51	Liu et al., 1985
	Taiwan	11/??/1982		Rn	+	3–4 times background			4.1	60		2 weeks	Liu et al., 1983
Uttarkashi (f)	India	10/20/1991		Rn	+	200	Not given	Not given	7	450	7	15	Virk and Baljinder, 1994
	India				+	300	Not given	Not given	7	270	7	15	Virk and Baljinder, 1994
	India				+	180	Not given	Not given	7	330	7	3	Virk and Baljinder, 1994
Himachal Pradesh (g)	India	4/9/1992		Rn	+	195	Not given	Not given	2.2	166		2	Virk and Baljinder, 1995
	India	5/23/1995		Rn	+	165	Not given	Not given	2.7	105		3	Virk and Baljinder, 1995
	India	1/12/1993		Rn	+	153	Not given	Not given	4.4	440		9	Virk and Baljinder, 1995
	India	1/12/1993		Rn	+	183	Not given	Not given	4.4	440		9	Virk and Baljinder, 1995
	India	7/21/1992		Rn	+	250	Not given	Not given	3.6	265		13	Virk and Baljinder, 1995
	India	8/5/1993		Rn	+	242	Not given	Not given	3.7	325		10	Virk and Baljinder, 1995
	India	8/5/1993		Rn	+	227	Not given	Not given	3.7	325		10	Virk and Baljinder, 1995
Maheshwaram	India	4/17/2002		Rn	+	100	Not given	Not given	<1	30	<1		Reddy et al., 2004
Chamoli (groundwater)	India	3/29/1999		Rn	+	69.66 Bq/l	56.69 Bq/l	Not given	6.8			2	Virk et al., 2001
Chamoli (soil gas)	India	3/29/1999		Rn	+	46.63 Bq/l	24.31 Bq/l	Not given	6.8			2	Virk et al., 2001
Chamoli	India	3/29/1999		He	+	5.6 ppm	5.1 ppm	Not given	6.8			5	Virk et al., 2001

		Jan 1991				background							
Chiba-ken Toho-oki	Japan	6/1/1990	59	Rn	−	5	2350	2225	6	200	2	2	Wakita et al., 1991
Fukushima	Japan	Jan 1987		Rn	−	2	2025	1975	6.6	260	0	0	Igarashi et al., 1990
Fukushima	Japan	Feb 1987		Rn	−	11	2025	1800	6.7	130	0	0	Igarashi et al., 1990
Fukushima	Japan	Apr 1987		Rn	−	9	2000	1825	6.6	110	0	0	Igarashi et al., 1990
Kobe	Japan	1/17/1995	14	Cl^-	+	10	13.85 ppm	15.3 ppm	7.2	20	4		Tsunogai & Wakita, 1995; Tsunogai & Wakita, 1996
Kobe	Japan	1/17/1995		Rn	−	5	3100	2950	7.2	260			Ohno & Wakita, 1996
Western Nagano prefecture	Japan	9/14/1984		Rn	+					65		2 weeks	Ui et al., 1988
Eastern Pyrenees	France	2/18/1996	7.7	Cl^-	+	36	0.272 mml/l	0.369 mml/l	5.2	29	5	10 to 13	Toutain et al., 1997
Hyogo-Ken Nambu Zisin	Japan	Sep 1984		He/Ar	−	25	0.112***	0.084***	6.9	50			Sugisaki et al., 1996
Hyogo-Ken Nambu Zisin	Japan	Sep 1984		N_2/Ar	−	10	126***	113***	6.9	50			Sugisaki et al., 1996
Hyogo-Ken Nambu Zisin	Japan	Sep 1984		CH_4/Ar	−	32	22***	15***	6.9	50			Sugisaki et al., 1996
Hyogo-Ken Nambu Zisin	Japan	Jan 1995		He/Ar	−	4	0.113***	0.109***	7.2	220	3 h	15 min	Sugisaki et al., 1996
Izu–Oshima–kinkai	Japan	1/14/1978	7.0	Rn	+	15%			7.0	25		5	Wakita et al., 1980
Hyogo-Ken Nambu Zisin	Japan	Jan 1995		N_2/Ar	−	2	132***	130***	7.2	220	3 h	15 min	Sugisaki et al., 1996
Hyogo-Ken Nambu Zisin	Japan	Jan 1995		CH_4/Ar	−	6	21.8***	20.6***	7.2	220	3 h	15 min	Sugisaki et al., 1996
Mindoro	Philippines	11/14/1994		Rn	+	600	Not given	Not given	7.1	48	7	22	Richon et al., 2003
Perpignan	France	1996		HCO_3^-	+	135 mg/L	80–110 mg/l		5.2	100			Perez, 1996
Perpignan	France	1996		Ca^{2+}	+	45 mg/l	20–30 mg/l		5.2	100			Perez, 1996
Perpignan	France	1996		Cl^-	+	75 mg/l	35 mg/l		5.2	100			Perez, 1996
Galicia	Spain	2 events, 11/29/1995 12/24/1995		Cl^-	+	26 mg/l	24 mg/l		4.64.6	90			Redondo et al., 1996
Galicia	Spain	2 events, 11/29/1995 12/24/1995		Br^-	+				4.6	90			Redondo et al., 1996
Galicia	Spain	2 events, 11/29/1995 12/24/1995		δD	+				4.6	90			Redondo et al., 1996

Note: The data through the earthquakes at Himachal Pradesh have been adapted from a table by Toutain and Baubron (1999).
Legend:
z = epicentral depth.
δa = deviation.
M = magnitude.
D = epicentral distance.
d = duration.
δt = days before event.
+, gas emission increase.
−, gas emission decrease.
*** unitless (ratio).
a Values from Hauksson (1981). This author does not supply time lag values.
b Hydrogen values from Sato et al. (1986). H_2 displays a very complex pattern probably linked to a sudden increase in seismicity (11 events of magnitude 5.2 to 6.7 within 6 months).
c The Big Bear earthquake swarm occurred on June 29 and 30. The main shock was $M = 4.8$ and was considered as the total event.
d Time lags vary at some sites which have several probes. No duration of anomalies is shown because of the track-etch method used.
Values of deviation of signal at each site are from one of the several probes. Values at one site (epicentral distance of 350 km) are either positive or negative, depending on the probe (Flores Humanante et al., 1990).
e According to data by Igarashi et al. (1995), we can assume the existence of two precursors, one lasting about 3 months and the other being a spike-like one occurring 7 days before the onset.
f Magnitudes were indicated to be 6.5 (Mb) and 7.0 (MS).
g Only anomalies above la have been selected. Graphical data are not enough precise to estimate values of duration and time lags of claimed anomalies.
Note: These notes are from the original table compiled by Toutain and Baubron (1999).

of positively and negatively charged particles, and an electric field is generated. In the rock samples, the near field E_s is related to the dipole moment p by

$$E_s = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}, \tag{9}$$

where r is the distance between the dipole and the antenna and ε_0 is the permittivity of free space. For earthquakes, Ogawa et al. (1985) propose that the electric fields actually generated are the induced field E_i in the VLF frequency range and the radiation field E_r for the LF frequency range. These fields are related to the dipole moment by

$$E_i = \frac{1}{4\pi\varepsilon_0}\frac{\dot{p}}{cr^2}, \tag{10}$$

and

$$E_r = \frac{1}{4\pi\varepsilon_0}\frac{\ddot{p}}{c^2 r}, \tag{11}$$

where c is the velocity of light and the dots represent derivatives with respect to time.

Pierce (1976) presented a model that relates changes in atmospheric electricity to the emission of radon gas from the earth. The radon gas alters certain parameters that affect atmospheric electricity, including fair-weather conductivity near the ground and the electric field (i.e., potential gradient). Specifically, the model predicts that the conductivity near the ground would increase by about 50%, while the electric field would decrease by about 30%.

4.5. Gas emission observations

In the late 1960s and early 1970s reports primarily from Russia and China indicated that concentrations of radon gas in the earth apparently changed prior to the occurrences of nearby earthquakes (Lomnitz, 1994). This stimulated a number of experiments in other parts of the world to monitor underground radon with time and to look for radon changes associated with earthquakes. Since radon is a radioactive gas, it is easy and relatively inexpensive to monitor instrumentally, and its short half-life (3.8 days) means that short-term changes in the radon concentrations in the earth can be monitored with very good time resolution. While other gases have also been looked at as possible earthquake precursors, the bulk of the experiments reported in the scientific literature have focused on radon.

In our literature survey, we found reports of 159 observations of changes in gas emissions from 107 earthquakes. Of these, there were 125 radon observations from 86 earthquakes, 7 observations of hydrogen gas from 7 earthquakes, 7 observations of helium gas from 7 earthquakes, 10 observations of helium/argon gas ratios from 10 earthquakes, 4 observations of methane/argon ratios from 4 earthquakes, 3 observations of nitrogen/argon ratios from 3 earthquakes, 2 observations of chlorine ions from 2 earthquakes, and 1 observation of mercury gas from 1 earthquake. There are also reports of possible changes in the emission of other gases, such as carbon monoxide and carbon dioxide, from the earth associated with earthquakes, but no specific measurements were reported in the papers we surveyed.

Table 2 contains the complete listing of gas emission anomalies found in our literature search along with estimates of the initiation time, strength and duration of the gas anomalies. Because the preponderance of data is concerned with radon gas changes, we summarize those results here.

There is a very wide range of earthquake magnitudes for which anomalous radon precursors have been reported. In the dataset in Table 2 the smallest earthquake magnitude is 1.5 and the largest is 7.9. Most of the observations are for earthquakes greater than magnitude 4.0. Radon gas changes up to 1200% relative to background radon concentration levels are reported in Table 2 although most of the changes are between 20% and 200%, with the most common reported change between 50% and 100% (Fig. 1). In Table 2, 83% of the observations reported that radon levels increased prior to the earthquake relative to the background radon levels.

In Fig. 2 the times of initiation of the radon anomalies and the durations of the radon anomalies are shown. Most of the radon anomalies began within 30 days of the earthquake, and most lasted less than 200 days. In some cases in Table 3 the radon anomaly initiated and terminated before the earthquake (δt greater than d in the Table 3), while in other cases the radon anomaly continued after the time of the earthquake (δt less than d in the Table 3). Thus, there does not appear to be any diagnostic behavior of either the beginning or the end of a radon anomaly that gives a consistent clue about when an earthquake is to happen. The best that can be said is that most of the time the earthquake takes places within a month of the time that an increase in radon gas is observed.

Fig. 3 shows the dependence of the magnitude of the reported radon anomalies on distance of the observation site to the earthquake epicenter and on the magnitude of the event. The greatest anomalies are reported closest to the epicenters of the coming earthquakes, suggesting that the

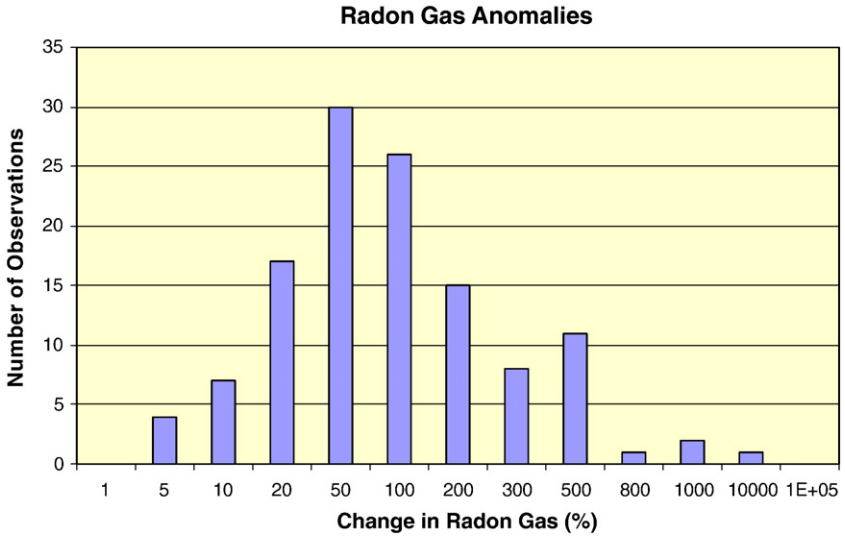

Fig. 1. Distribution of reported maximum changes in radon gas concentrations in the earth (in percent relative to the background radon levels) prior to earthquakes. Most of the changes are between 20% and 200%. The vertical axis represents the number of observations for each data range.

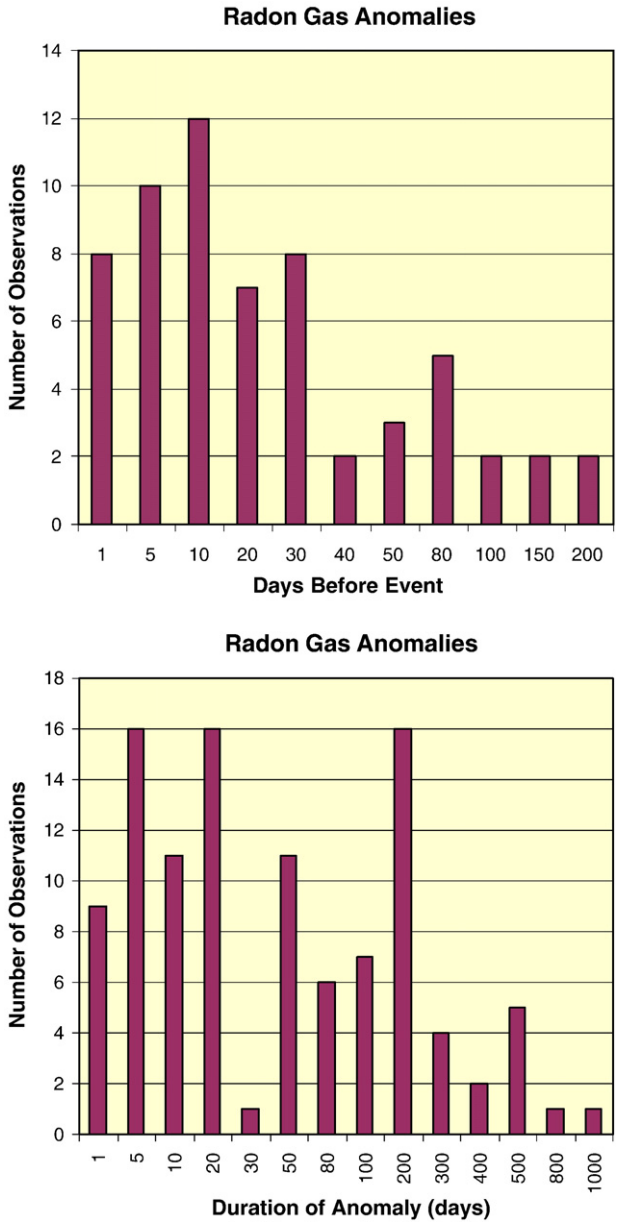

Fig. 2. Distribution of reported times of initiation of the radon anomaly prior to the earthquake (top) and of the durations of the radon anomaly (bottom). Most of the radon anomalies began within 30 days of the earthquake and lasted less than 200 days.

radon anomalies are associated with some physical processes in or near the earthquake fault zone. On the other hand, the amplitude of the radon anomaly does not seem to depend on the magnitude of the coming earthquake. This appears to indicate that whatever causes the anomalous radon emissions does not control the size of the earthquake. The significant amount of scatter in the data precludes the determination of any useful regression curves of radon anomaly as a function of either distance or magnitude. On the other hand, curves that represent the possible extremal values from the data in Table 3 are plotted in Fig. 3, and the corresponding equations. for these lines are summarized in Table 4. These curves are intended to place a possible upper bound on the expected anomaly radon values as a function of magnitude and distance as determined by the data collected in this study.

Fig. 4 analyzes the dependence of magnitude of the coming even with the start time of the radon anomaly relative to the time of the earthquake and with the duration of the anomaly. Greater times between the start of the anomaly and the earthquake as well as longer durations of the radon anomalies appear to be associated with larger event magnitudes. Thus, in an earthquake prediction scheme, the longer the duration of a radon anomaly, the larger the earthquake that might be expected. Again, line segments representing possible extremal values of the data as a function of magnitude are plotted in Fig. 4.

The paucity of data for the other types of gases in Table 2 precludes analyses similar to those of Figs. 1–4. However, some general statements can be made about the observational data for these other gases. First, for the other gases the distribution of reported anomaly amplitudes, time durations, time of initiation before the event, and distance to the epicenter appear in all cases to be similar to the observations for radon gas. The amplitudes of the anomalies seem to vary from gas to gas, with the largest reported increase being 100,000% for an observation of H_2 prior to an earthquake. This would seem to suggest that other gases besides radon may give higher amplitude gas emissions prior to earthquakes if they were widely monitored. Finally, while radon tends to increase in emission before earthquakes, this appears to be true of some but not all of the gases in Table 2. Of these other gases for which data were collected, H_2 (6 of 7 observations), He/Ar (7 of 10 observations) and Cl^- (2 of 2 observations) show gas increases before the earthquakes, while He (4 of 7 observations), CH_4/Ar (3 of 4 observations) and N_2/Ar (3 of 3 observations) report gas decreases before the earthquakes.

4.6. Gas emission models

Thomas (1988) provides a summary of physical processes proposed to explain geochemical precursors, including gas emissions, to earthquakes. Although many different models have been proposed in the literature to account for the various observed geochemical precursors, most can be associated with one of the following mechanisms:

- Physical and/or chemical release by ultrasonic vibration (UV model);
- Chemical release due to pressure sensitive solubility (PSS model);
- Physical release by pore collapse (PC model);
- Chemical release by increased loss or reaction with freshly created rock surfaces (IRSA model);
- Physical mixing due to aquifer breaching and/or fluid mixing (AB/FM model).

These mechanisms are briefly described below. Readers are referred to the review paper of Thomas (1988) for the original references.

4.7. Ultrasonic vibration model

This model proposes that loosely-bound constituents in subsurface rocks can be released by ultrasonic vibration. Laboratory studies have indicated that rocks react more readily with water when ultrasonic vibration is applied. Field studies have also shown that geochemical anomalies can be generated in response to a subsurface explosive discharge, similar to those commonly used in seismic exploration.

Critics of this model contend that the relatively high frequencies necessary to release chemical species from subsurface rocks are either too weak or completely absent in the frequency spectrum of earthquakes. In addition, geochemical anomalies associated with explosions are typically much smaller that those associated with earthquakes. Also, these explosion-induced anomalies occur some time after the explosion itself, indicating that some other mechanism may be generating these anomalies.

4.8. Pressure sensitive solubility model

This model proposes that increases in dissolved chemical species in groundwater are caused by increases in fluid pressure due to precursory stress changes. This mechanism is unlikely to contribute significantly to the generation of geochemical anomalies, because the required stress changes are on the order of tens to hundreds of bars. Even though stress changes of this order are common in earthquakes,

Table 3
Reported precursory groundwater level changes associated with earthquakes.

Earthquakes with reported groundwater precursors								
Earthquake	Mag.	Date	*D* [km]	*A* [m]	*T* [day]	*t* [day]	Reference	Notes
Turkmenia, former U.S.S.R.	7.3	10/5/1948	10	−1.300	180.0	7.0	Mil'kis, 1984	*
Turkmenia, former U.S.S.R.	7.3	10/5/1948	10	−0.800	60.0	45.0	Mil'kis, 1984	*
Turkmenia, former U.S.S.R.	7.3	10/5/1948	90	−0.400	225.0	40.0	Mil'kis, 1984	*
Turkmenia, former U.S.S.R.	7.3	10/5/1948	90	−0.600	225.0	40.0	Mil'kis, 1984	*
Turkmenia, former U.S.S.R.	7.3	10/5/1948	90	−0.400	225.0	40.0	Mil'kis, 1984	*
Turkmenia, former U.S.S.R.	7.3	10/5/1948	90	+/−0.5	150.0	70.0	Mil'kis, 1984	*
Uzbekistan, former U.S.S.R.	7.3	5/17/1976	200	−2.000	1.0	0.5	Ishankulov and Kalugin, 1976	*
Uzbekistan, former U.S.S.R.	7.3	5/17/1976	530	−16.000	300.0	40.0	Mil'kis and Voronin, 1983	*
Tadzhikistan, former U.S.S.R.	6.3	1/31/1977	210	1.000	135.0	—	Sultankhodzhaev and Chernov, 1978	*
Turkmenia, former U.S.S.R.	4.5	3/25/1977	120	−0.080	60.0	25.0	Zhukov et al., 1978	*
Tadzhikistan, former U.S.S.R.	5.0	12/6/1977	25	2.000	150.0	—	Sultankhodzhaev and Chernov, 1978	*
Kirgizia, former U.S.S.R.	6.6	3/25/1978	300	−0.500	35.0	20.0	Orolbaev, 1984	*
Kirgizia, former U.S.S.R.	6.6	3/25/1978	140	−0.200	14.0	10.0	Orolbaev, 1984	*
Kirgizia, former U.S.S.R.	6.8	11/2/1978	140	−0.800	3.0	1.0	Mavlyanov and Sultankhodzhaev, 1981	*
Uzbekistan, former U.S.S.R.	5.1	12/11/1980	150	−0.110	40.0	30.0	Kissin et al., 1984a	*
Uzbekistan, former U.S.S.R.	5.1	12/11/1980	150	−0.005	5.0	5.0	Kissin et al., 1984a	*
Uzbekistan, former U.S.S.R.	5.1	12/11/1980	160	−0.030	1.0	0.5	Kissin et al., 1984a	*
Kazakhstan, former U.S.S.R.	5.3	12/31/1982	95	0.130	2.0	—	Ospanov and Mizev, 1985	*
Tadzhikistan, former U.S.S.R.	5.9	12/26/1984	100	8.100	3.0	—	Sultankhodzhaev et al., 1986	*
Kuril Islands, former U.S.S.R.	7.5	3/22/1978	270	−0.030	7.0	2.5	Monakhov, 1981	*
Kuril Islands, former U.S.S.R.	7.0	6/21/1978	450	−0.045	6.0	3.0	Monakhov et al., 1980	*
Kuril Islands, former U.S.S.R.	5.2	10/11/1978	90	−0.070	6.0	2.0	Monakhov et al., 1980	*
Kuril Islands, former U.S.S.R.	5.6	12/2/1978	440	−0.090	9.0	2.0	Monakhov et al., 1979	*
Kuril Islands, former U.S.S.R.	5.4	2/25/1979	95	−0.040	5.0	1.5	Monakhov, 1981	*
Kuril Islands, former U.S.S.R.	6.3	2/15/1980	170	−0.030	6.0	2.0	Monakhov, 1981	*
Baykal area, former U.S.S.R.	5.0	10/2/1980	25	−0.300	60.0	—	Golenetskii et al., 1982	*
Lutt Plateau, Iran	6.7	1/16/1979	400	−0.350	21.0	14.0	Mil'kis & Voronin, 1983	*
Hindu Kush, Afghanistan	6.6	5/2/1981	450	0.015	4.0	3.0	Kissin et al., 1984b	*
Singhai, China	6.8	3/24/1971	20	−0.300	20.0	7.0	Wang et al., 1984a	*
Singhai, China	6.8	3/24/1971	—	−0.410	30.0	1.0	Hamilton, 1975	*
Liaoning, China	7.3	2/4/1975	40	−0.100	8.0	5.0	Raleigh et al., 1977	*
Liaoning, China	7.3	2/4/1975	145	−0.030	4.0	2.0	Raleigh et al., 1977	*
Hebei, China	7.8	7/28/1976	5	−15.000	2640.0	5.0	Wang et al., 1984b	*
Hebei, China	7.8	11/15/1976	30	−13.000	1090.0	5.0	Wang et al., 1984b	*
Hebei, China	6.9	11/15/1976	100	−3.000	100.0	30.0	Alimova and Zubkov, 1983	*
Liaoning, China	5.6	11/27/1977	20	−0.500	1.2	—	Wang et al., 1984a	*
Liaoning, China	5.6	11/27/1977	20	−0.580	—	0.4	Cai and Shi, 1980	*
near Izu Peninsula, Japan	7.0	1/14/1978	35	+/−2.0	288.5	30.0	Alimova and Zubkov, 1983	*
Izu Peninsula, Japan	6.6	6/29/1980	30	0.480	40.0	15.0	Yamaguchi, 1980	*
California, U.S.A.	5.0	2/24/1972	—	−0.050	25.0	10.0	Kovach et al., 1975	*
California, U.S.A.	4.7	4/9/1972	—	−0.100	40.0	15.0	Kovach et al., 1975	*
San Jacinto, California, U.S.A.	5.5	2/25/1980	35	0.450	3.7	3.4	Merifield and Lamar, 1981	*
Kettleman Hills, California, U.S.A (2 wells)	6.1	8/4/1985	35	+3.0 cm, +3.8 cm		3	Roeloffs and Quilty, 1997	
Taiwan	6.3	12/29/1984	—	0.050	0.0	0.0	Yu and Mitchell, 1988	
Taiwan	6.3	6/12/1985	—	0.030	0.0	0.1	Yu and Mitchell, 1988	
Taiwan	6.2	1/16/1986	—	0.240	0.0	0.0	Yu and Mitchell, 1988	
Izu–Oshima–kinkai, Japan	7.0	1/14/1978	30	−0.300	0.0		Wakita, 1984	
southwest Japan	6.6	3/18/1987	226	0.2 ml/s	15 min	0	Kawabe et al., 1988	
Tokyo Bay, Japan	5.9	2/2/1992	90–110	0.040	2.0	1.5	Igarashi et al., 1992	
Tokyo Bay, Japan	5.9	2/2/1992	90–110	0.034	2.0	1.5	Igarashi et al., 1992	
Tokyo Bay, Japan	5.9	2/2/1992	90–110	−0.100	1.0	0.5	Igarashi et al., 1992	
Tokyo Bay, Japan	5.9	2/2/1992	90–110	0.200	0.0		Igarashi et al., 1992	
Tokyo Bay, Japan	5.9	2/2/1992	90–110	−0.038	0.0		Igarashi et al., 1992	
Tokyo Bay, Japan	5.9	2/2/1992	90–110	0.010	0.0	1.0	Igarashi et al., 1992	
Hokkaido, Japan	8.1	10/4/1994	1260	−50 cm		10	Igarashi et al., 1996	
Sanriku, Japan	7.8	12/28/1994	800	−50 cm		10	Igarashi et al., 1996	
Izu Peninsula, Japan (6 swarms, >1000 events/day)	≥2.5	9/1995–10/1995,10/1996, 3/1997, 4/1998–5/1998, 5/2002, 6/2002	30	0.0024 m/h	<1 day	<1	Koizumi et al., 1999, Koizumi et al., 2004	
Tono Mine, Japan	6.1	9/24/1990	510	0.5	5 days	0	King et al., 2000	
Tono Mine, Japan	7.2	10/4/1994	220	0.5	10 days	0	King et al., 2000	
Tono Mine, Japan	7.5	12/28/1994	800	0.5	10 days	0	King et al., 2000	
Tono Mine, Japan	8.1	1/17/1995	1260	0.5	30 days	0	King et al., 2000	
Tono Mine, Japan	6.6	9/5/1996	290	0.2	5 days	0	King et al., 2000	
Tono Mine, Japan	5.8	3/16/1997	50	2	6 months	0	King et al., 2000	
Koyna-Warna, western India	4.4	4/25/1997	3	+3 cm, +7 cm (2 wells)	23 days	23	Chadha et al., 2003	
Koyna-Warna, western India	4.3	2/11/1998	12	+5 cm	3 days	3	Chadha et al., 2003	
Koyna-Warna, western India	4.7	4/6/2000	24	+2.5 cm	28 days	28	Chadha et al., 2003	
Koyna-Warna, western India	5.2	9/5/2000	12–20	−(0.4–8) cm (7 wells)	24–28 days	24–28	Chadha et al., 2003	
Thessaloniki, Greece	4.8	10/20/1988	33–46	5–10 cm	5 days	5	Asteriadis and Livieratos, 1989	

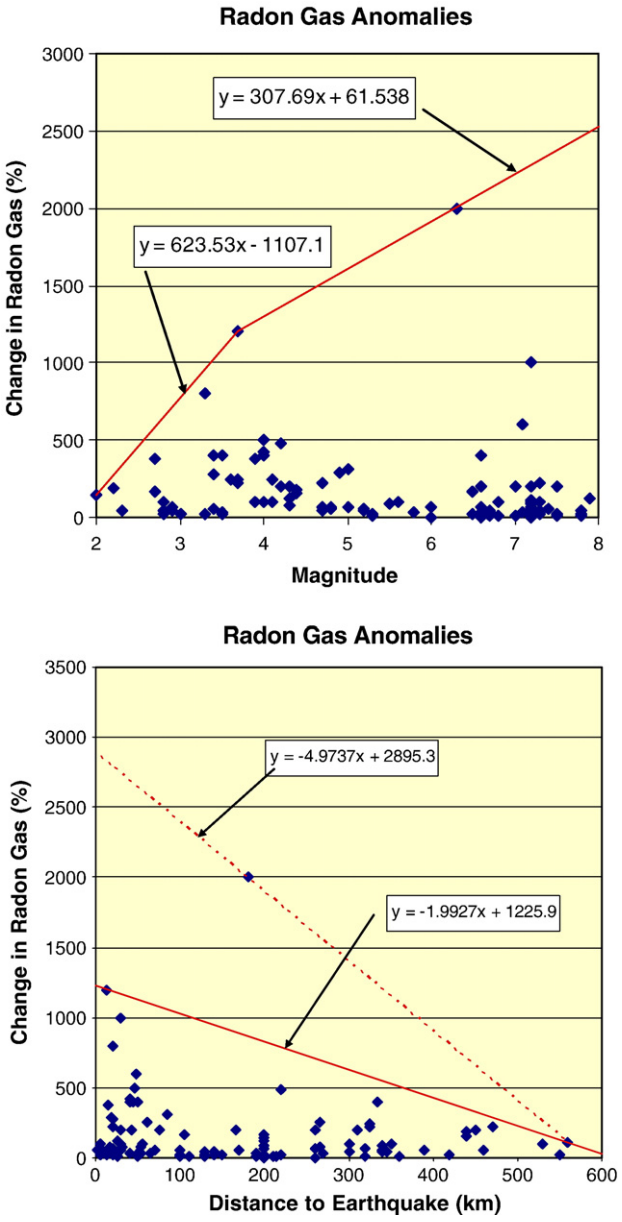

Fig. 3. Distribution of reported changes in radon gas concentrations with distance to the earthquake (top) with event magnitude (bottom). The greatest anomalies are reported closest to the epicenters, but no dependence on magnitude is seen. Curves representing the possible extremal values of the data sets are also shown. On the bottom figure, two different extremal lines are shown, where the solid line ignores the one extreme data point at about 180 km epicentral distance.

there is little evidence that these stress changes are transferred to the fluid phase in the rocks.

4.9. Pore collapse model

This model suggests that, as stresses in the earth increase prior to an earthquake, the pore volume in the rocks collapses, thereby releasing chemical species into the groundwater, generating a geochemical anomaly. Decreases in rock pore volume have been demonstrated in a number of laboratory and field studies.

The importance of the pore collapse model to the study of earthquake precursors is not well established. Laboratory studies indicate that volume losses in rocks tend to occur at relatively low stress levels and tend to be small. In fact, high stresses in porous rocks result in an increase in pore volume for most rocks. Also, decrease in pore volume is an irreversible process and would not account for the repeated and cyclic nature of precursory geochemical precursors.

4.10. Increased reactive surface area model

For this model, it is proposed that microfracturing prior to major earthquakes leads to increases in ion and gas concentrations in the groundwater. The fracturing process has two effects. The first is that it allows trapped gases to escape from the rock matrix. The second is that it produces fresh silicate surfaces, which are believed to increase the rate of reaction with groundwater.

Laboratory studies indicate that microfracturing and the associated dilatancy can increase the porosity of rocks appreciably, from 20% up to as much as 400%. Reaction with fresh rock surfaces has been shown to significantly increase ions in groundwater. Also, laboratory studies have indicated that the release of gases, most notably radon, can increase substantially at the stress levels associated with microfracturing (Holub and Brady, 1981). Field studies have indicated a correlation with increased radon concentrations in groundwater and regional stress and deformation changes.

The major uncertainty associated with this model is the fact that laboratory studies have indicated that rock dilatancy and the associated increases in pore volume only become important in rocks near the failure strength. This would indicate that the mechanism should be confined to a small volume of rock close to the fault. This is in conflict with the observations of geochemical precursors at significant distances from seismogenic faults. However, it has been argued that this model does not consider the importance of stress corrosion cracking and subcritical crack growth, which can occur at relatively low stress levels and high moisture content.

4.11. Aquifer breaching/fluid mixing model

This model can be used to account for anomalous changes in groundwater geochemistry as the result of mixing of chemical species from two distinct aquifer systems. The advantage of this model is that it can account for both increases and decreases in chemical species and gas concentrations, as well as the concurrent temperature changes that often accompany these geochemical precursors.

The mechanism of fluid mixing is believed to be due to precursory fracturing of hydrologic barriers that separate the individual aquifer systems. A similar mechanism has been proposed by Byerlee (1993) to explain the compartmentalization of high-pressure fluid regions in the vicinity of faults. This mechanism was cited by Fenoglio et al. (1994a,b; 1995) to support their conclusion that the electrokinetic mechanism is the process by which transient ULF magnetic field precursors were generated prior to the Loma Prieta earthquake.

4.12. Groundwater level change observations

Changes in groundwater level changes prior to earthquakes have been reported back to early historic times (Martinelli, 2000). This is

Notes to Table 3:
*Compiled by Kissin and Grinevsky, 1990.
D = epicentral distance.
A = amplitude (+, groundwater rise; −, groundwater drop).
T = time (period of time from the beginning of the precursor to the earthquake origin time).
t = extremum time (period of time from the onset of a precursor extremum to the earthquake origin time).

Table 4
Summary of equations for extremal value curves.

Figure number	Type of anomaly	Physical quantity (y vs. x)	Equation
3	Radon gas	Change in radon gas vs. magnitude	$y = 307.69x + 61.538$
3	Radon gas	Change in radon gas vs. magnitude	$y = 623.53x - 1107.1$
3	Radon gas	Change in radon gas vs. distance to earthquake	$y = -4.9737x + 2895.3$
3	Radon gas	Change in radon gas vs. distance to earthquake	$y = -1.9927x + 1225.9$
4	Radon gas	Anomaly duration vs. magnitude	$y = 359.72x - 1005.8$
4	Radon gas	Anomaly duration vs. magnitude	$y = 135.59x - 71.186$
4	Radon gas	Days before event vs. magnitude	$y = 42.857x - 85.714$
7	Water level change	Water level change vs. distance to earthquake	$y = -0.9867\mathrm{Ln}(x) + 7.5439$
7	Water level change	Water level change vs. distance to earthquake	$y = 0.9867\mathrm{Ln}(x) - 7.5439$
7	Water level change	Water level anomaly vs. magnitude	$y = 4.2632x - 17.053$
7	Water level change	Water level anomaly vs. magnitude	$y = -4.2632x + 17.053$
8	Water level change	Time of anomaly maximum before event vs. magnitude	$y = 16.207x - 48.31$
8	Water level change	Time of anomaly maximum before event vs. magnitude	$y = 57.5x - 230$
8	Water level change	Start of anomaly before event vs. magnitude	$y = 69.25x - 196.25$
8	Water level change	Start of anomaly before event vs. magnitude	$y = 150x - 600$

not surprising, because water is essential to human life and the use of wells to provide water for human settlements has been important going back to the beginning of human civilization. Any unusual changes in groundwater levels, particularly dug wells that either drop significantly in level or even go dry, would be noted and be a cause for concern. Unfortunately, most such reports are anecdotal rather than of a careful scientific measurement, and so they would not be reflected in the database accumulated in this study.

The groundwater change observations are summarized in Table 3. There are 52 observations from 32 earthquakes, with the earthquake magnitudes ranging up to 7.8. Most of the reports come from within 200 km of the epicenter of the earthquake, with the greatest distance for an observation being 530 km.

Fig. 5 shows the distribution of the maximum water level changes reported prior to the earthquakes in Table 3. While the maximum changes ranged from a 15 m drop in water level to an 8 m rise, most of the changes were less than 1 m. In 72% of the cases, the groundwater level was observed to drop before the earthquake. Fig. 6 indicates that most of the changes in groundwater levels began within about a year of the coming earthquake, but some much earlier than that. However, generally the greatest change in groundwater level was observed within about 40 days of the coming earthquake.

Fig. 7 shows the dependence of the amplitude of the groundwater level change with distance to the earthquake epicenter and with magnitude of the coming earthquake. Fig. 8 illustrates the start time of the groundwater anomaly and the time of the greatest anomaly as a function of the magnitude of the coming earthquake. While there are not as many data points as for the radon data, the tendencies in these two figures are very similar to those seen in the radon dataset. The greatest anomalies tend to be observed closest to the event epicenters, and the start times and the times of the greatest anomalies tend to increase with the magnitude of the coming earthquake. Also, there is a hint in Fig. 7 that the greatest groundwater level changes may be associated with the largest magnitude events. As for the gas emission data, the significant amount of scatter in the groundwater data precludes the determination of any useful regression curves as a function of either distance or magnitude. Here also curves that represent the possible extremal values from the data are plotted in Figs. 7 and 8, and the corresponding equations for these lines are summarized in Table 4.

In many ways, many of the characteristics of the groundwater change precursors documented in this study, such as the time of the initiation of the anomalies, the time of the greatest anomaly, and the dependence of the amplitude of the anomaly on magnitude and epicentral distance, seem to parallel the same characteristics in the radon gas anomalies. This is probably because both phenomena are associated with changes in rock permeability and perhaps porosity during the days, weeks and perhaps months before an earthquake rupture initiates.

4.13. Groundwater level change models

Changes in groundwater levels have been observed before certain earthquakes and are believed to be in response to volumetric strain in the earth's crust. However, in order to determine the groundwater level changes are directly related to crustal strain, nontectonic causes of water level changes must be considered. These include barometric pressure changes, tidal effects, rainfall, and extraction of groundwater and other fluids such as oil and gas. A summary of evaluating groundwater level changes as earthquake precursors is given by Roeloffs (1988).

The largest precursory water level changes are observed in confined aquifers (Roeloffs and Quilty, 1997). For these aquifers, the change in reservoir fluid pressure Δp is related to the incremental change in volumetric strain Δe by (Rice and Cleary, 1976)

$$\Delta p = -(2GB/3)[(1+\nu_u)/(1-2\nu_u)]\Delta e, \tag{12}$$

where G is the shear modulus, B is Skempton's coefficient, and n_u is the undrained Poisson's ratio. The change in water level Δh is related to Δp by

$$\Delta h = \frac{\Delta p}{\rho g}, \tag{13}$$

where r is the fluid density and g is the gravitational acceleration. For typical values of $G = 3$ Gpa, $B = 0.8$, and $n_u = 0.3$, the water level change would be 52 cm per 10^{-6} strain (Roeloffs, 1988), with a rise in water level corresponding to compressive strain and a drop in water level corresponding to dilatational strain.

For unconfined aquifers, the water level change is given by

$$\Delta h = -(H/n)\Delta e, \tag{14}$$

where H is the saturation thickness of the aquifer and n is the porosity. For a 100 m saturated aquifer with 2% porosity, the expected change in water level is 0.5 cm per 10^{-6} strain (Roeloffs, 1988), significantly less than that for a confined aquifer.

As mentioned above, water level changes due to nontectonic origin can occur and must be accounted for in order to accurately determine the amount of water level change due to crustal strain. Barometric pressure changes can contribute to changes in water levels in a groundwater aquifer. An increase in barometric pressure Δb compresses the aquifer, causing the pressure in the aquifer to increase by

$$\Delta p = (b/3)[(1+\nu_u)/(1-\nu_u)]\Delta b. \tag{15}$$

In an open well, however, the increase in barometric pressure causes a downward force on the fluid surface, counteracting the effect

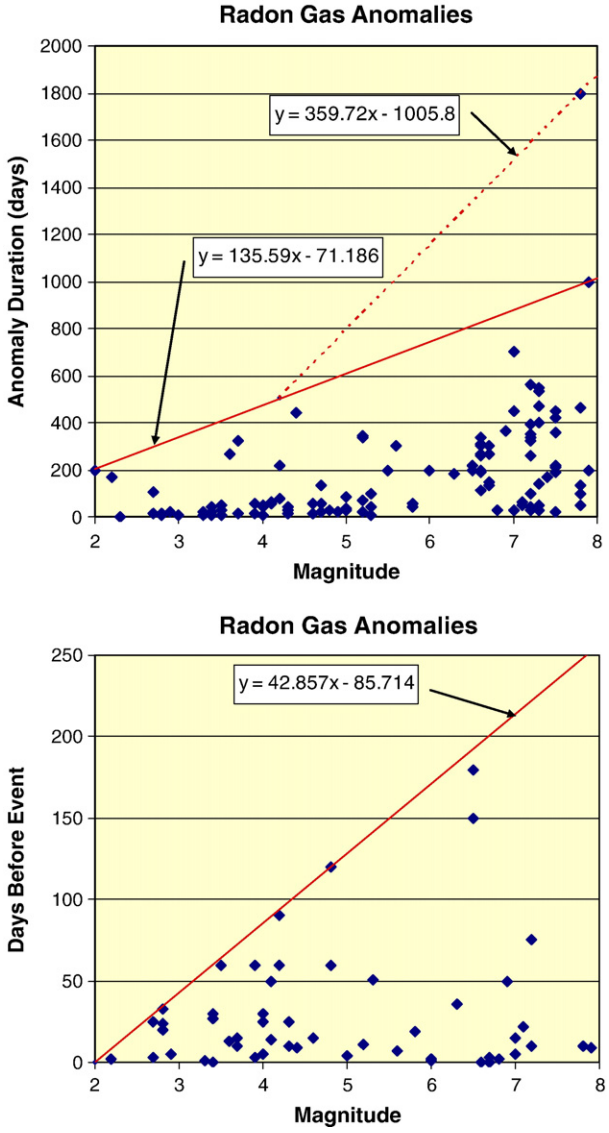

Fig. 4. Distribution of the initiation times (top) and durations (bottom) of the radon anomalies with event magnitude. The greatest initiation times and anomaly durations are associated with the largest earthquakes. Curves representing the possible extremal values of the data sets are also shown. On the top figure, the solid extremal line ignores the one extreme data point at about magnitude 8, while the combination of the solid and dashed extremal lines include this data point.

of the increase in the reservoir fluid pressure. The net effect is a decrease in water level given by

$$\Delta h = -(1/\rho g)[1 - (B/3)(1+\nu_u)(1-\nu_u)]\Delta b. \quad (16)$$

This relation predicts a decrease of 0.52 cm in water level per 1 mbar of pressure change (Roeloffs, 1988).

Another important effect that causes changes in water levels is the earth's tidal response. The change in water level due to the earth's tidal response is given by

$$\Delta h = -\frac{K\Delta e}{n\rho g}, \quad (17)$$

where Δe is now the volumetric strain induced in the earth by the tidal response and K is the bulk modulus of water (Bredehoeft, 1967). This relation assumes the compressibility of the individual rock grains is negligible compared to the compressibility of the reservoir, and it is not valid for low porosities. This relation can be used with a porosity vs. depth relation to determine the sensitivity to the tidal response as a function of depth.

Roeloffs (1988) discusses the effect of rainfall on groundwater level changes. Rainfall acts to recharge the aquifer by providing a transient source of fluid into the reservoir. Similar effects can also be considered when fluids are withdrawn from aquifers.

The effects of rainfall are often delayed by some period of time, depending on the thickness and permeability of the overburden, and the distance between the rainfall source. This time delay can be as long as several months. In addition, a threshold amount of rainfall may be required before reservoir recharge is initiated.

4.14. Ground temperature change observations

There have been relatively few reported observations of temperature changes in the earth prior to earthquakes. This is probably due to a lack of experiments to look for such an effect. The thermal

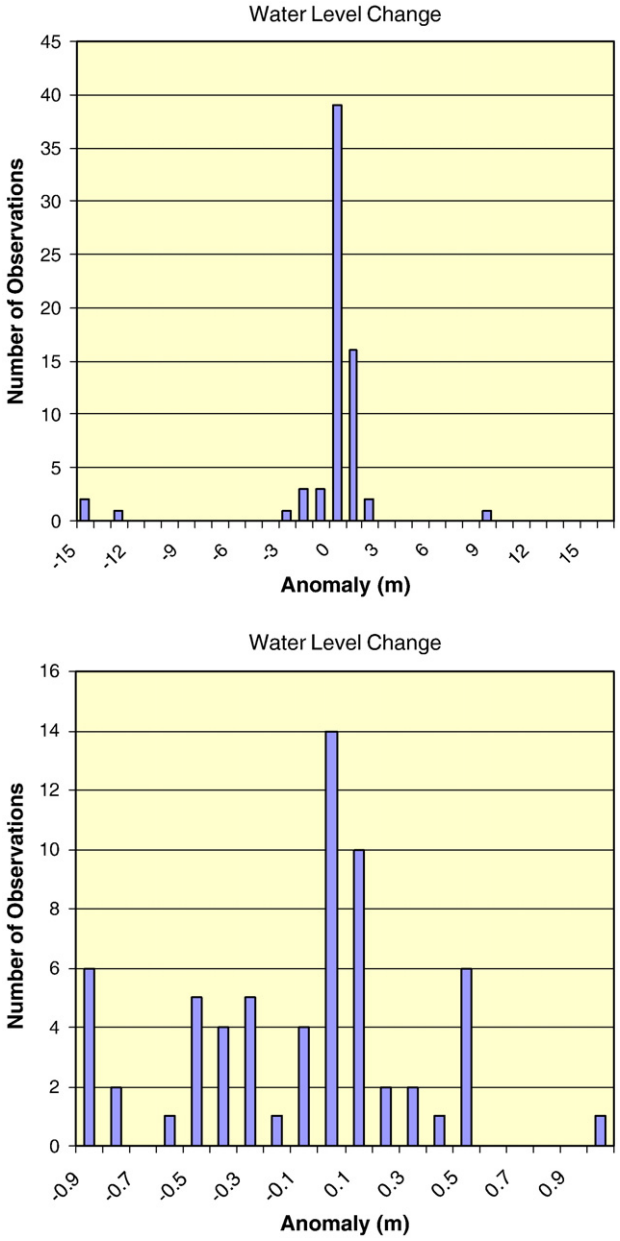

Fig. 5. Distribution of reported maximum changes in groundwater level prior to earthquakes. The top plot shows all the observations, while the bottom plot shows the observations of water level changes between −1 m and +1 m.

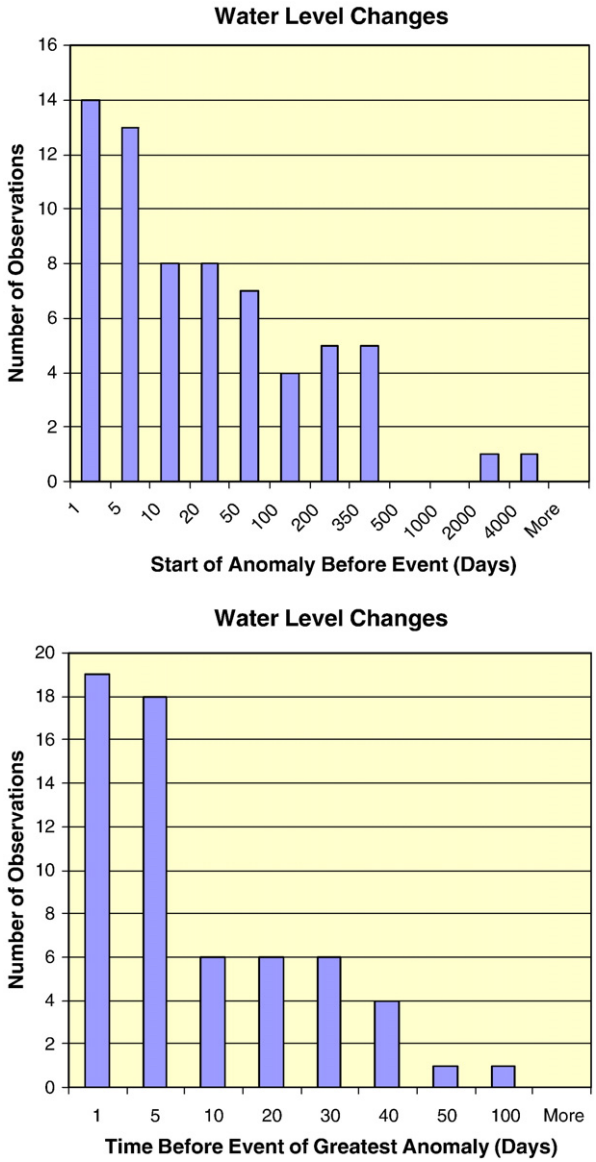

Fig. 6. Distribution of reported times of initiation of the groundwater anomaly prior to the earthquake (top) and of the times of the greatest groundwater change (bottom).

conductivity of rock is quite low, and it takes many years for a significant temperature change to diffuse just a few meters in rocks. Thus, from a theoretical point of view, one would not expect to observe thermal anomalies in rocks prior to earthquakes.

On the other hand, as documented above the flow of groundwater and gases through the rocks and soils might be altered during some time period before an earthquake occurs in a region. Particularly in areas of active tectonics and volcanics, such alterations of the flow of water in the earth before an earthquake might sometimes allow that water to come into contact with hotter rock bodies at depth and raise the temperatures of near-surface groundwaters. In some cases, the alterations in the rock pore structure at depth before an earthquake might cut off a flow of geothermally warmed water to the surface, leading to a cooling of near-surface water temperatures. Of these two possible scenarios for precursory temperature changes, the former would be easier to observe since the rock and soil around the cooler water would remain at a warmer temperature for a long period of time due to the poor thermal conductivity of the rock and soil.

The temperature change dataset assembled in this study consisted of 15 observations from 12 earthquakes ranging in magnitude from 2.3 to 7.0 (Table 5). Of the 15 observations, 10 reports came from measurements taken at hot springs in volcanic areas. Most of the observations were taken within 50 km of the epicenters of the coming earthquakes, although the greatest reported epicentral distance for an anomaly was 470 km. In all cases an increase in ground temperature was reported, with the largest change being 6 °C and most of the changes being <1 °C. Five of the temperature changes in groundwater were reported to have been coseismic, i.e., having occurred at the time of the earthquake, while 5 were reported to take place within the 10 days prior to the earthquake. The rest of the observations did not report the time at which the temperature change was reported.

All of these reported changes in temperature associated with earthquakes were from Greece and Japan. Both are areas of active plate subduction with active volcanoes and numerous geothermal features. It is not known if there might be temperature changes in the groundwater of non-geothermal areas prior to earthquakes, as there

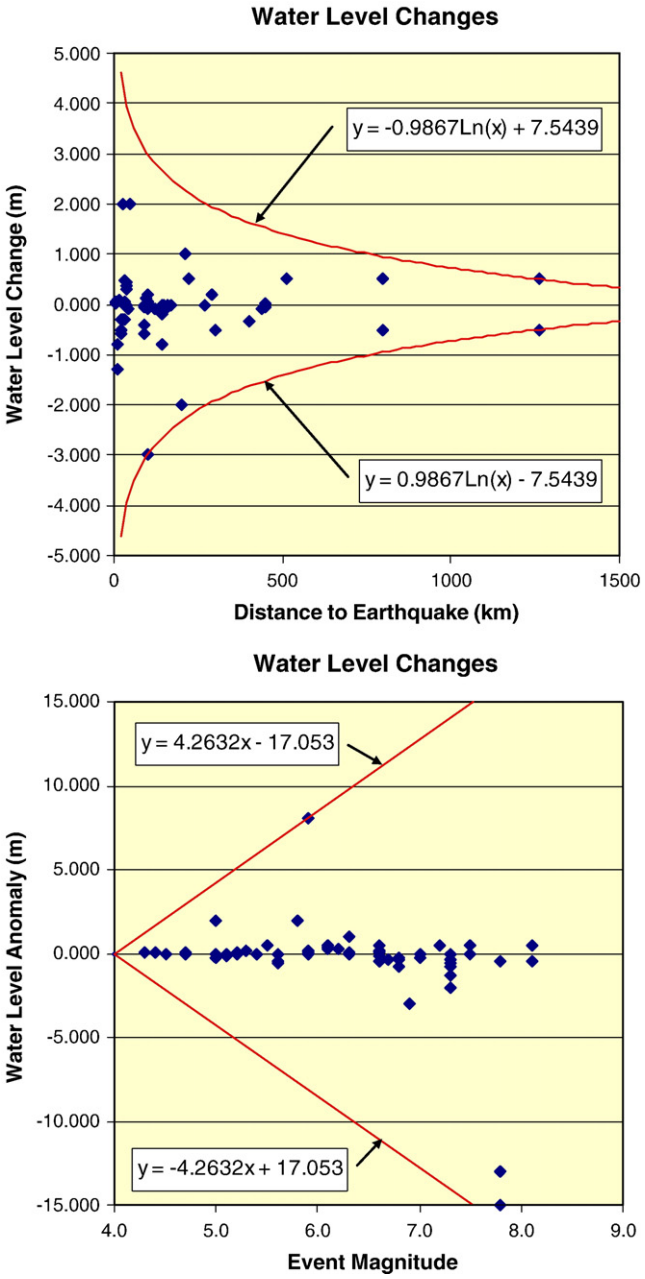

Fig. 7. Distribution of reported changes in maximum groundwater level with distance to the earthquake (top) with event magnitude (bottom). The greatest anomalies are reported closest to the epicenters and perhaps for the largest earthquakes. Curves representing the possible extremal values of the data sets are also shown.

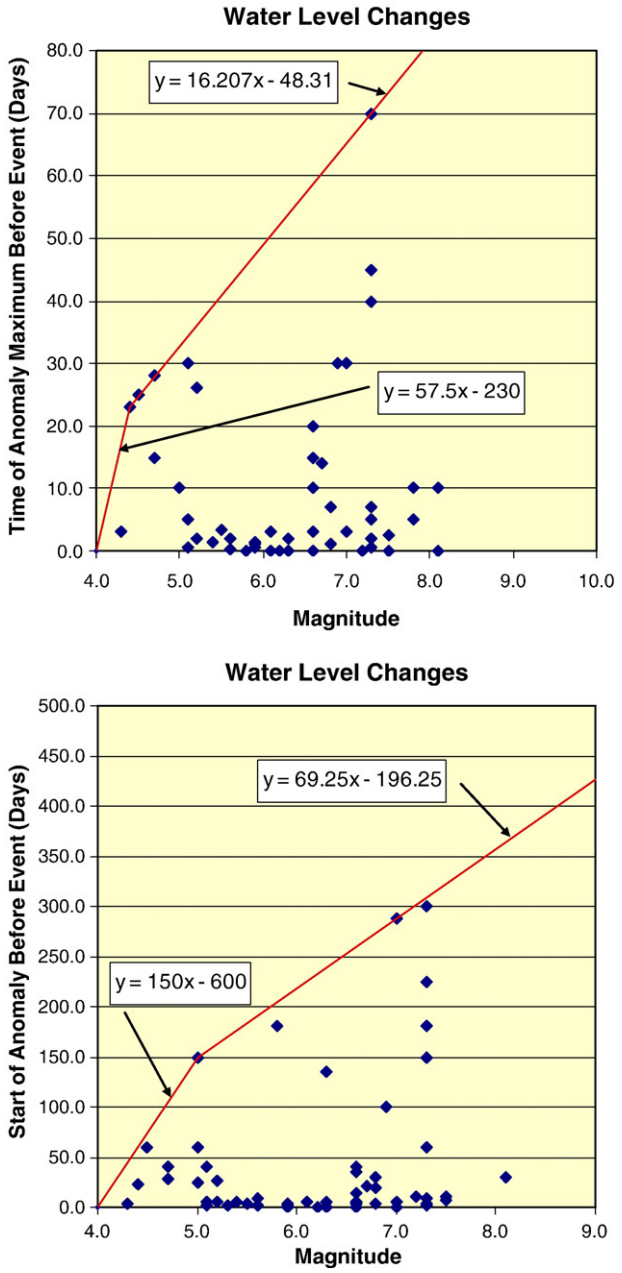

Fig. 8. Distribution of the times of the greatest groundwater changes (top) and of the start time of the groundwater changes (bottom) with event magnitude. The greatest groundwater level changes and start times are associated with the largest earthquakes. Piecewise linear curves representing the possible extremal values of the data sets are also shown.

have been no reported studies. However, it is possible that such would not be the case. The San Andreas Fault has no geothermal anomaly associated with it (e.g., Lachenbruch and Sass, 1992), an unexpected observation because shear strain heating from the multitude major earthquakes on that fault over geologic time was thought to have led to an increase in heat flow and rock temperatures in the vicinity of that fault. This observation could mean that temperature changes may not take place prior to earthquakes in non-volcanic or geothermal areas.

4.15. Ground temperature change models

Precursory temperature anomalies are usually associated with changes in groundwater levels and with geochemical anomalies, although frictional heating on fault surfaces could contribute to ground temperature changes. Because rocks have a relatively low thermal conductivity, any such temperature-related changes that may occur at depth in the earth would take a long time to reach the surface. Therefore such a temperature anomaly is expected to be relatively small.

Temperature anomalies associated with groundwater level changes could be significant, however. Heat generated at depth within the earth would be more efficiently transported to the surface by the convective flow of groundwater than by thermal conduction through the rock itself. Should pre-earthquake dilatancy be a significant pre-earthquake effect, the opening of new pores and the widening of old pore as the rock becomes dilatant may allow groundwater and gases trapped in the rock to circulate through deeper, and therefore warmer, rock. Near the surface of the earth, geothermal gradients can be 1.5 °C–3.5 °C per 100 m, except at geothermal areas and volcanoes where they can be much higher. Thus, if the groundwater is suddenly allowed to circulate through rock that is 200 m deeper than before the dilatancy began, then the surface groundwater may increase in temperature by several degrees. The amount of temperature increase that would observed at the surface would be controlled by the depth to which the groundwater would circulate, the temperatures at the new depths where the water is circulating, the speed at which the deep groundwater would come to the surface, and the ratio of the volumes of the deep and shallow groundwaters.

4.16. Surface deformation observations

There has been a longstanding interest in looking for surface deformations (uplifts, downdrops, tilts, strains, strain rate changes, etc.) prior to earthquakes (Rikitake, 1976). Many crustal earthquakes of M6 and greater have been associated with deformations at the surface of the earth, and in some cases there is evidence that there were deformations that were precursory to the occurrences of the earthquakes (Rikitake, 1976; Lomnitz, 1994). Unfortunately, until very recently, documenting such changes has been very difficult. Surface leveling and laser-ranging geodetic measurements were the most accurate way to document ground deformations over regions that are tens of kilometers in dimension. However, such measurements are time consuming and expensive to make, and the feasible time between individual measurements is months to years. Modern GPS and satellite-based SAR interferometry measurements are now available to produce geodetic position changes with individual measurements separated by minutes to days. However, these new technologies have yet to capture surface deformations precursory to strong earthquakes.

The sparse ground-deformation dataset compiled in this study (Table 6) reflects the formerly difficult nature of making such measurements prior to earthquakes and the lack of successful precursory measurements using the new technologies. We compiled a dataset of 12 tilt observations from 9 earthquakes, 5 strain observations from 2 earthquakes, and 3 strain rate change observations from 1 earthquake. The earthquakes ranged in magnitude from 3.0 to 7.1. Most of the measurements were made at epicentral distances of less than 100 km, although the measurements range as far as 400 km from the epicenter in one case. The reported deformations took place months to days before the earthquakes, and the larger amplitude strains and tilts seem to be associated with the larger earthquakes.

4.17. Surface deformation models

Models to predict surface deformation in the vicinity of a fault involve the ability to model the behavior of the fault itself. These models can indicate what type of surface deformations can occur and

Table 5
Reported precursory temperature changes associated with earthquakes.

Earthquakes with reported temperature–variation precursors								
Earthquake	Mag.	Date	Precursor time	Anomaly [°c][a]	Ambient temp before eq [°c]	Dist. from epicenter [km]	Ref.	Notes
Thessaloniki, Greece	4.8	10/20/1998	2 days	0.2	16.6	33	Asteriadis and Livieratos, 1989	From well data
Thessaloniki, Greece	4.8	10/20/1998	5 days	0.7	15.5	41	Asteriadis and Livieratos, 1989	From well data
Thessaloniki, Greece	4.8	10/20/1998	Coseismic	0.7	17.6	41	Asteriadis and Livieratos, 1989	From well data
Thessaloniki, Greece	4.8	10/20/1998	Coseismic	0.5	19.8	41	Asteriadis and Livieratos, 1989	From well data
Bay of Patras, Greece	5.4	7/14/1993	12 h	6	17	1.5	Soter, 1999	From sea bed (20 m below surface, 10 m above sea bed, 650 m from shore)
Kawazu, Japan	5.4	1976	Not reported[b]	0.3	60	28	Mogi et al., 1989	From hot springs data
Izu–Oshima–Kinkai, Japan	7	1978	10 days	1.3	59.5	31	Mogi et al., 1989	From hot springs data
Miyagi–Ken–Oki, Japan	7.4	1978	Not reported[b]	0.6	60	470	Mogi et al., 1989	From hot springs data
Ito–Oki, Japan	5.4	1978	Not reported[b]	1.2	59.8	16	Mogi et al., 1989	From hot springs data
Ito–Oki (swarm), Japan	3.8	1979	Not reported[b]	0.5	59.3	10	Mogi et al., 1989	From hot springs data
Izu–Hanto–Toho–Oki, Japan	6.7	1980	3 days	1.75	59	16	Mogi et al., 1989	From hot springs data
Ito–Oki, Japan	3.7	1981	Not reported[b]	0.5	59.5	11	Mogi et al., 1989	From hot springs data
Sagami Bay, Japan	5.7	Aug-82	Coseismic	1	59.7	46	Mogi et al., 1989	From hot springs data
Ito–Oki, Japan	2.3	Jul-82	Coseismic	0.7	59.4	6	Mogi et al., 1989	From hot springs data
Ibaraki–Ken–Oki, Japan	7	Jul-82	Coseismic	0.6	59	290	Mogi et al., 1989	From hot springs data
Datong, China	6.1	10/18/1989	2 days	2–4 avg., 5–6 max.	10	£ 200	Qiang et al., 1997	Thermal infrared satellite (Meteosat)
Oroville, California	5.8	8/1/1975	1 day	>100 min	50 min	<200	Valette-Silver and Silver, 1991; Silver and Valette-Silver, 1992	Old Faithful Geyser, Calistoga, California (eruption interval data)
Morgan Hill, California	6.1	4/24/1984	1 day	25 and 50 min (bimodal signal)	40 min	<200	Valette-Silver and Silver, 1991; Silver and Valette-Silver, 1992	Old Faithful Geyser, Calistoga, California (eruption interval data)
Loma Prieta, California	7.1	10/18/1989	60 h	172 min	90 ± 2 min	180	Silver et al., 1990; Valette-Silver and Silver, 1991; Silver and Valette-Silver, 1992	Old Faithful Geyser, Calistoga, California (eruption interval data)

[a] Positive, unless otherwise indicated.
[b] It is inferred from the paper that these precursors are on the order of a couple months, but it is not clearly stated.

whether or not these deformations are likely to be detected with the available surface instruments.

Fault models attempt to specify the mechanical behavior along the faults. This mechanical behavior is modeled using a constitutive relationship that defines the rate- and state-dependent behavior of friction along the fault surface. Dieterich (1972; 1978; 1979) defined such a law and Ruina (1983) later modified it. The steady-state coefficient of friction μ_{ss} is given by

$$\mu_{ss}(V) = \mu^* + (\mathbf{a} - \mathbf{b})\ln(V / V^*), \quad (18)$$

where V is the slip velocity, V^* is an arbitrary reference velocity such that $\mu_{ss}(V^*)=\mu^*$, and **a** and **b** are constitutive parameters. The parameter **a** is a measure of the magnitude of the instantaneous change in the coefficient of friction as the velocity changes, and **b** is a measure of the decay in the coefficient of friction at the new velocity. The decay of the coefficient of friction is exponential with decay constant D_c, called the characteristic decay distance.

An alternative form of the constitutive relation for the fault is given by Tse and Rice (1986). This form uses shear stress instead of the coefficient of friction and is given by

$$\tau_{ss}(V) = \tau^* + \sigma_n(\mathbf{a} - \mathbf{b})\ln(V / V^*), \quad (19)$$

where t_{ss} is the steady-state shear stress, s_n is the normal stress, and $t^*=t_{ss}(V^*)$.

Lorenzetti and Tullis (1989) used the Tse and Rice (1986) model to study crustal strike-slip earthquakes and to calculate displacement, velocity, strain, and strain rate distributions associated with these earthquakes. Their results indicate that strain rates are the most readily detectable signals, because the magnitudes of these signals are larger than the detectability thresholds of strains by current instrumentation due to the presence of noise that cannot yet be removed from the data.

4.18. Precursory seismicity observations

This precursor is well studied by ground-based seismic instruments, but it is included here for two reasons. First, because many of the earth's strong earthquakes are preceded within hours, days or weeks by smaller earthquakes called foreshocks, this premonitory seismic activity may well be related in some way to the non-seismic precursors described above. Second, in principle, satellite-based detection of seismic ground motions is possible, and in the future there may be interest in developing such a technology to complement surface-based observations.

No formal table of foreshock observations was compiled for this study, as the list would be very extensive but not particularly informative for the purposes of this paper. However, we present here some summary statistics of earthquake foreshock activity from published analyses.

The most important summaries of foreshocks on a global basis were published by Jones and Molnar (1976) and Reasenberg (1999). The former study reported on $M>7.0$ earthquakes from 1950 to 1973 and showed that 44% of these strong earthquakes had a least one foreshock ($M>4.5$) within 40 days of the main shock. The latter study analyzed $M>6.0$ earthquakes from 1977 to 1996 and showed that 13.2% had a least one foreshock ($M>5.0$) with 10 days and 75 km of the main shock. It is likely that many earthquakes have smaller foreshocks than those reported in these studies, and so these results probably represent a lower bound on global foreshock rates before strong earthquakes. However, no statistical work to document the rates of smaller magnitude foreshocks has been done due to uneven earthquake detection worldwide.

One significant point of these foreshock studies is that most foreshocks seem to take place during the same time period (within

Table 6
Reported measured precursory ground deformations associated with earthquakes.

Earthquakes with reported ground-deformation precursors								
Area	Date	*M*	Type	*D* [km]	Anomaly	Time before event	References	Notes
San Andreas Fault, California	7/73 to 3/7 (28 events)	2.5–4.3	Tilt	<30 km	2×10^{-6} (tilt direction often changes prior to earthquakes)	Typicallty 1 month	Johnston and Mortensen, 1974	
Kalapana, Hawaii	11/29/1975	7.2	Strain		3.5×10^{-4}	5 months	Wyss et al., 1981	
Friuli, Italy	5/6/1976	6.5	Tilt	15	200 sec	3 years	Dragoni et al., 1985	
Friuli, Italy	9/15/1976	6.5	Tilt	15	200 sec	3 years	Dragoni et al., 1985	
Izu–Oshima, Japan	1/14/1978	7.0	Compressional strain change S of epicenter		2.5×10^{-6}	6 weeks	Linde and Suyehiro, 1983	
Izu–Oshima, Japan	1/14/1978	7.0	Compressional strain change NE of epicenter		4×10^{-5}	days	Linde and Suyehiro, 1983	
Homestead Valley, California	1/21/1979	3.1	Pre-seismic creep	32	−100 mm	40 h	Leary and Malin, 1984	
Homestead Valley, California	2/17/1979	2.0	Pre-seismic creep	8	+100 mm	5 days	Leary and Malin, 1984	
Homestead Valley, California	3/9/1979	2.4	Pre-seismic creep	24	−200 mm	2 days	Leary and Malin, 1984	
Homestead Valley, California	3/15/1979	5.1	Pre-seismic creep	150	−100 mm	20 h	Leary and Malin, 1984	
Lytle Creek, California	10/19/1979	4.1	Stress transient	15	0.14 MPa	2–4 weeks	Clark, 1981	
Irpinia, Italy	11/23/1980	6.5	Tilt	250	1.5×10^{-5} radians	2 months	Allegri et al., 1983	
Irpinia, Italy	11/23/1980	6.5	Tilt	250	2×10^{-5} radians	6 months	Allegri et al., 1983	
Kamchatka Gulf	8/17/1983	6.9	Leveling	100	2.4 mm/day	2 days	Fedotov et al., 1992	
Friuli region, Italy	2/1/1988	4.1	Tilt	1.8	1.5×10^{-5} radians	2 months	Dal Moro and Zadro, 1999	
Friuli region, Italy	10/5/1991	3.9	Strain	2.9	9×10^{-7}	9 days	Dal Moro and Zadro, 1999	
Spitak, Armenia	12/7/1988	6.9	Strain	100	3×10^{-7}	0–8 days	Neresov and Latynina, 1992	1, 2
Spitak, Armenia	12/7/1988	6.9	Tilt	100	1×10^{-7}	0–8 days	Neresov and Latynina, 1992	1, 2
Spitak, Armenia	12/7/1988	6.9	Strain	125	1×10^{-8}	0–8 days	Neresov and Latynina, 1992	1, 2
Spitak, Armenia	12/7/1988	6.9	Strain	300	1.5×10^{-6}	0–8 days	Neresov and Latynina, 1992	1, 2
Spitak, Armenia	12/7/1988	6.9	Tilt	300	2×10^{-5}	0–8 days	Neresov and Latynina, 1992	1, 2
Spitak, Armenia	12/7/1988	6.9	Strain	400	9×10^{-7}	0–8 days	Neresov and Latynina, 1992	1, 2
Spitak, Armenia	12/7/1988	6.9	Tilt	400	1×10^{-7}	0–8 days	Neresov and Latynina, 1992	1, 2
Loma Prieta, California	10/17/1989	7.1	Strain rate change	31	From −10.8 1.0 to −18.9±5.0 mm/yr	1.3 years	Lisowski et al., 1990	
Loma Prieta, California	10/17/1989	7.1	Strain rate change	31	From 6.6±1.1 to 2.0±5.0 mm/yr	1.3 years	Lisowski et al., 1990	
Loma Prieta, California	10/17/1989	7.1	Strain rate change	43	From −8.7±1.5 to −23.8±7.1 mm/yr	1.3 years	Lisowski et al., 1990	
Loma Prieta, California	10/17/1989	7.1	Creep retardation	0–80 (6 sites)	From 10.3 to 6.8 mm/yr	July 1987 to September 1989	Breckenridge and Burford, 1990	
Central Appenines, Italy	4/3/1991	3.3	Tilt	7.6	1.34×10^{-7}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	7/13/1991	3.7	Tilt	35.8	6×10^{-9}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	5/5/1992	3	Tilt	11.5	1.4×10^{-8}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	8/25/1992	3.9	Tilt	23.1	3.8×10^{-8}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	8/27/1992	3.1	Tilt	9.1	3.9×10^{-8}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	10/24/1992	3.7	Tilt	27.7	1.1×10^{-8}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	10/24/1992	3.5	Tilt	27.7	6×10^{-9}	months	Bella et al., 1995a,b	3
Central Appenines, Italy	7/16/1993	3.5	Tilt	28	6×10^{-9}	months	Bella et al., 1995a,b	3
Hollister, Calfiornia	11/28/1974	5.2	Tilt	11.2	7×10^{-6} radians	30 days	Mortensen and Johnston, 1976	
Briones Hills, California	1/8/1977	4.3	Tilt	5.5	2×10^{-6} radians	1 month	Jones et al., 1977	
Calaveras Fault, California	8/29/1978	4.2	Tilt	6.0	8.6×10^{-6} radians	63 h	Iwatsubo and Mortensen, 1979	
Calaveras Fault, California	8/29/1978	3.9	Tilt	4.5	8.6×10^{-6} radians	63 h	Iwatsubo and Mortensen, 1979	
Calaveras Fault, California	9/5/1978	2.5	Tilt				Iwatsubo and Mortensen, 1979	
Niigata, Japan	6/16/1964	7.5	Vertical crustal movement	30	5 cm	5 years (1959–1964)	Fujii and Nakane, 1997	
Japan Sea	5/26/1983	7.7	Strain (about 100 events)	90	1×10^{-8} to 3 10^{-8} (typically 3 h duration)	5 months	Linde et al., 1988	
Joshua Tree, California	4/23/1992	6.1	Fault normal extension		30±3 mm	3/8/1992–3/9/1992	Shifflett and Witbaard, 1996	
Landers, California	6/28/1992	7.3	Fault normal extension		30±3 mm 24±6 mm	6/7/1992–6/8/1992 6/6/1992	Shifflett and Witbaard, 1996	
Landers, California	6/28/1992	7.3	Horizontal slip (dextral)		20±9 mm 24±6 mm	6/6/1992	Shifflett and Witbaard, 1996	
Big Bear, California	6/28/1992	6.2	Fault normal extension		30±3 mm 24±6 mm	6/7/1992–6/8/1992 6/6/1992	Shifflett and Witbaard, 1996	
Big Bear, California	6/28/1992	6.2	Horizontal slip (dextral)		20±9 mm 24±6 mm	6/6/1992	Shifflett and Witbaard, 1996	
Tonankai, Japan	12/7/1944	8.1	Uplift		4 mm	1 day	Mogi, 1985	
Tonankai, Japan	12/7/1944	8.1	Tilt		1×10^{-5} sec	1 day	Mogi, 1985	

[1]These values are approximate, as they were read off a figure.
[2]The background signal (i.e., tidal strain) levels are not available from this report.
[3]The exact precursor times are not provided.

about 30 days of the main shock) when the most frequently reported non-seismic precursors (i.e., radon anomalies, groundwater level changes, EM emissions) seem to take place. Thus, it is possible that there are some physical links in the generation mechanisms of all of these precursors.

4.19. Precursory seismicity models

Scholz (1990) argued that foreshock activity is probably a manifestation of the nucleation process that ultimately results in the main earthquake. He noted that foreshocks tend to occur in the immediate vicinity of the hypocenter of the later main shock, they increase in frequency of occurrence as the time of the main shock is approached, and they are typically much smaller in magnitude than the main shock. Dilatancy may explain short-term quiescences just prior to the main shock in some foreshock sequences. The models for precursory crustal deformation, described earlier, also can be applied to explain foreshock sequences since rapid crustal deformations may be associated with some seismic energy release. The individuality of foreshock sequences from one earthquake to another may mean that foreshocks are not an intrinsic part of the nucleation process on a fault but rather are part of that nuclear process (Scholz, 1990).

5. Discussion of the observations and models of earthquake precursors

The data and analyses described in the previous sections can be combined to make some general statements about the characteristics of anomalous precursors that may precede earthquakes. From the observational data, it appears that the largest amplitude anomalies tend to occur before the largest magnitude earthquakes. This seems most clear for the groundwater level and the gas emission datasets, while there are insufficient data to generalize this argument for the other precursors looked at in this study. Nevertheless, such a characteristic is implicit in the physical models describing all of the precursors. A second common characteristic for all of the precursors is that the strongest anomalies seem to occur within about 1 month of the coming earthquake, and the closer in time to the occurrence of the earthquake, the larger the number of precursor types that might be observed. The observations of increasing EM anomalies and foreshock activity in the hours just prior to many earthquakes suggest that this might be a critical preparatory time in a fault region just before an earthquake occurs.

For all of the precursor types researched here, it appears that most of the anomalies tend to be observed within a couple hundred kilometers of the coming earthquake epicenter. This is consistent with the scaling relationships of fault length and earthquake magnitude. Large earthquakes move large volumes of rock in the earth. For example, the average fault lengths for earthquakes of magnitude 5, 6, 7 and 8 are approximately 5 km, 15 km, 40 km, and 100 km, respectively. Thus, most precursory earthquake anomalies seem to be observed in or near the region in the earth where the largest deformations are experienced in the eventual earthquake. There are some important implications of the size of the area around an earthquake epicenter where precursory phenomena might be observed. First, if an anomaly suggesting a coming earthquake is observed, the area on the earth in which that earthquake might take place is relatively limited, giving some spatial resolution for earthquake predictions. Second, it is currently not known how large a surface area on the earth may emit an EM anomaly, show a radon anomaly, or experience a groundwater change prior to an earthquake.

The models for the various earthquake precursors analyzed in this study also have some important common features. The most important common feature is that the earthquake precursory anomalies are thought to be driven by rapid and probably non-linear strain and strain changes within the earth in the rock near or in the fault zone at the region of the eventual earthquake rupture. Non-linear stress–strain and dilatant behavior prior to rock fracture has long been observed in laboratory experiments when small pieces or rock (a few cm on a side) are fractured (Scholz, 1990). The rapid deformations just prior to fracture combined with changes in the groundwater and gas flow in the earth due changes in porosity and permeability in the rock volume that fractures in the earthquake can generate, in one way or another, all of the earthquake precursors studied here (e.g., Press and Siever, 1978; Lomnitz, 1994). It is not known how well the small-scale laboratory experiments may apply to the large-scale rupture processes that take place within the earth. Also, there are many free parameters that are poorly known in the models discussed in the previous section of this report. Nevertheless, the laboratory experiments and theoretical models do provide some plausible physical explanations for the observed earthquake precursory data.

Regarding individual precursors, some comments should be made about the observational data. The EM observations compiled in this study give a somewhat confused picture about exactly what kinds of precursory signals might be seen before earthquakes. The frequency content of the observed anomalous signals compiled in our work seems to vary considerably from study to study. One study indicates that the anomalous precursory signals are confined in latitude but observed at a wide range of longitudes, while another study show confinement of the anomalous signals over a narrow longitude band but at essentially all latitudes. Much still probably must be learned about precursory EM signals and earthquakes. We point out that there was one surface-based observation of a strong ionospheric signal at about 4–5 MHz recorded at Boulder, Colorado that started about 2 h before the great Alaskan earthquake of 1964 (Davies and Baker, 1965). This earthquake (M9.2) was the second largest earthquake known since earthquake recording began in the late 1800s. Thus, as with the 1989 Loma Prieta ULF observation, there are some provocative observations that suggest that the earth may well radiate EM energy at perhaps many different frequencies prior to the initiation of a strong earthquake.

The paucity of studies of temperature change data prior to earthquakes is most consistent with the lack of interest in this topic by most earthquake scientists. There have been very few experiments to look for such a phenomenon. Furthermore, the lack of a heat flow anomaly at the San Andreas Fault may mean that San Andreas earthquakes are not accompanied by precursory temperature changes. Even so, in volcanic areas that are also prone to strong earthquakes, changes in the flow of groundwater and gas emission may be accompanied by anomalous changes in the temperature of the surface groundwater and gas emissions. This could be a target for future space-based research. It could also have application in the search for the imminence of major volcanic eruptions.

Surface deformations precursory to earthquakes are of interest to seismologists. In part this is because laboratory and theoretical rock deformation studies prior to fracture, especially the observation of dilatancy in rocks just prior to their fracture, indicate that in many cases surface deformations might be observed. As noted above it has been very expensive, laborious and time consuming to make surface deformation observations in the past. The advent of relatively inexpensive continuous GPS observations and of methods to measure ground deformations using satellite-based synthetic aperture radar interferometry (IN-SAR) are rapidly changing the way that surface deformations will be observed for scientific studies. For example, the Plate Boundary Observatory (PBO) is a major effort by the NSF to fund a very large number of continuous, permanent GPS stations in the western U.S. The purpose of the PBO is to monitor real-time deformation of the western plate boundary of North America (Silver, 1998). Thus, in the future many of the past constraints limiting surface deformation studies in earthquake-prone areas are likely to be eliminated.

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Zhukov, V.S., Lykov, V.I., Sukhomlin, V.F., 1978. Some results of electrometric observations in the Ashkabad Geodynamical Test Area, Izv. Akad. Nauk Turk. SSR, Phys.-Tech. Chem. Geol. Sci. 2, 41–46 (in Russian).

Moore-Love, Karla

From: Kate & Chris <samsa@pacifier.com>
Sent: Thursday, April 23, 2015 5:49 AM
To: Council Clerk – Testimony; Moore-Love, Karla
Subject: HLC Testimony of Friends of Reservoirs and Dee White--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm
Attachments: 2015-03-30 Dee White Testimony at Washington Park HLC Hearing.pdf; 2015-03-29 Friends of Reservoirs HLC Testimony on Washington park attaching IRP resolution.pdf

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

If they have not been already, please admit the above documents into the record on the above case. Let the record show the testimony of Dee White and of Floy Jones of Friends of Reservoirs regarding the 2003 Independent Review Panel and the municipal resolution adopting the IRP's recommendations to seek risk mitigation measures that preserve Portland's open reservoirs.

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

Adam, Hillary

From: Dee White <deewhite1@mindspring.com>
Sent: Sunday, March 29, 2015 6:22 PM
To: Adam, Hillary
Subject: LU14-249689DM Demolition Review for WA Park comment for HLC March 30, 2015 meeting
Attachments: The Portland Alliance Panel votes not to bury reservoir.pdf

Historic Landmarks Commission
March 30, 2015

Re: CASE FILE:LU14-249689DM(PC# 14-139549)
Demolition Review for Washington Park Reservoirs
#3 and #4 and the Weir Building

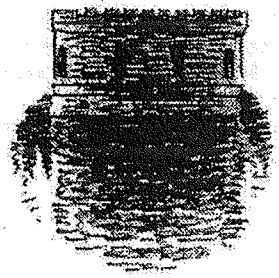
Comment from:
Dee White
3836 SE 49th
Portland, OR

The Zoning Code Approval Criteria on page 6 references the Historic Resource Review section 33.445.330, titled Demolition of Historic Resources in a Historic District. This reads: Demolition of other historic resources within a Historic District requires demolition review to ensure their historic value is considered. The Review period also ensures that there is an opportunity for the community to fully consider alternatives to demolition.

This opportunity for the community **has never taken place**. The Water Bureau made the decision to demolish the reservoirs behind closed doors. The public was NEVER given any meaningful opportunity to consider alternatives to demolition. One of the reasons for this proposal to demolish is to address the LT2 rule. This federal regulation, which is in review until 2016, requires that all public water systems that store water in open reservoirs must either cover the reservoirs or treat the reservoir discharge. There is no demolition alternative. **The public has never been allowed to weigh in on the either of the alternatives that would preserve the reservoirs until the LT2 review is completed in 2016.**

In 2003 the City created the Mt Tabor Independent Review Panel for the purpose of reviewing the options for meeting this same LT2 rule and keeping the reservoirs secure. It was created in response to the massive amount of criticism for the lack of public participation in the decision to bury the reservoirs at Mt Tabor and WA Park. In the **attached report** from Dave Mazza, who was a member of this 13 member panel, you can read about the panel's findings and the final vote AGAINST burying the reservoirs.

So, essentially, in 2004, once all of the facts were brought to light, much of it by the public, and presented to the independent panel, the panel voted not to move forward with the burial.



FRIENDS *of the* RESERVOIRS

Citizens joining to protect Portland's historic reservoirs and water system

3534 S.E. Main Street, Portland, OR 97214 www.friendsofreservoirs.org

www.lists.pdx.edu/mttabor

March 29, 2015

LU 14-249689 DM (PC# 14-139549) **Demolition Review for Washington Park Reservoirs #3 and #4 and the Weir Building**

Comments submitted via e-mail by Floy Jones on behalf of Friends of the Reservoirs

The Friends of the Reservoirs strongly opposes the proposal to demolish Reservoir 3 and Reservoir 4 and the Weir buildings at Washington Park. This plan does not meet criteria and otherwise creates new and unique cancer-causing public health risks. Demolition is not required by the onerous EPA LT2 regulation nor is it necessary for any other reason. Low cost alternate compliance has already been financed by ratepayers who will continue to pay not only for installation of the grillwork and liner installed in 2003 as preparation for installation for reservoir covers as well as for the purchased covers. Reservoir covers meet the EPA LT2 requirements. Ratepayer are also financing the Washington Park reservoir upgrades completed between in 2003 and 2010, costs that will increase over time as they are debt financed. A secondary LT2 compliance option, one that would preserve the open reservoirs but has never been fully considered is also available, "treatment at the outlet". Unlike demolition employing either of these options would likely meet LU criteria for historic resources.

The Portland Water Bureau has not met the requirements for compliance with Chapters 33.445 and 33.846

The Portland Water Bureau has not demonstrated that they considered the historic value of Portland's open reservoir resources when making the backroom and unsupported decision to demolish the Washington Park open reservoirs, a decision made by Water Bureau engineers in 2008. Also,the community was never afforded opportunity to fully consider the alternatives to demolition. There is no need to demolish the Washington Park reservoirs 3 and 4 or the Weir building when other less detrimental and lower-cost EPA compliant alternatives exist yet have not been fully considered.

The Portland Water Bureau and their cozy revolving-door consultants have been trying for decades to force "fun" reservoir burial projects as described in 2013 by Water Bureau engineer Stan Vanderberg at a wholesale customer water managers meeting. In 2004 Water Bureau Administrator Mort Anoushirivani when asked at a public infrastructure meeting why the Water Bureau was spending so much money on revolving-door consultant studys while deferred maintenance (as referenced by a 2004 City Auditor report) was being avoided, responded by saying "designing and building is glamorous and maintenance is boring." When trying to force unsupported reservoir demolition and covering projects between 2001 and 2004, PWB PR staff including Tim Hall repeatedly told the public that the reservoirs were not historic resources. It was not the Water Bureau that worked to place the reservoirs on the National Register of Historic Places in 2004 but several members of the Friends of the Reservoirs, a Water Bureau watchdog organization with members representing both sides of the river that formed in response to 2001 line-item budget decisions to cover Washington Park reservoirs and demolish the Mt. Tabor reservoirs.

At a budget presentation earlier this month the Portland Water Bureau failed to include the historic open reservoirs as assets, let alone as the significant assets they have been and remain.

The Portland Water Bureau was the only utility in the entire nation that was secretly seated at

development of any reservoir compliance plan.

Friend of the Reservoirs devoted many tens of thousands of volunteer hours over the last 12 plus years in service of protecting the significant and well-functioning resources that are Portland's historic open reservoirs. We have worked with a broad-base of community stakeholders including many neighborhood associations, neighborhood coalitions, public health, businesses and business coalitions, environmental and social justice organizations -all of whom have written to City Council and/or the Congressional delegation in support of alternatives to the current reservoir plan. Over 30 community organizations have opposed the Water Bureau's burial and covering plans since 2002. At least 22 of these organizations have written to City Council, the Congressional delegation and/or testified in support of alternatives since 2010.

40 members of the public attended the Water Bureau's first public meeting (2014) related to the Washington Park demolition plans. No information was presented on any of the viable options that would avoid demolition. Overwhelmingly, everyone in attendance at this meeting save one opposed the Water Bureau's demolition plans. By design the Water Bureau has avoided providing opportunity for the community to fully consider alternatives to demolition. Just as in 2002 the Water Bureau wants to limit ratepayer discussion to what happens after the degradation of significant water system and community assets.

APPROVAL CRITERIA. Proposals to demolish a historic resource will be approved if the review body finds that one of the following approval criteria is met:

1. Criteria: Denial of a demolition permit would effectively deprive the owner of all reasonable economic use of the site. This is not the case here.
   RESPONSE: The Portland Water Bureau would be able to continue to use both of the open reservoirs if needed, Reservoirs 3 and 4, as part of the drinking water system and be in compliance with federal regulations if they install a reservoir cover at very low cost. Prior to construction of the Powell Butte II tank the city had an excess of in town storage at Tabor and Washington Park as reported by the PWB to the Oregon Health Authority and the EPA, 50 million gallons of excessive storage, thus the Water Bureau has not been utilizing all of the storage at Washington Park (or at Tabor) though not being clear with the public about this fact.
   In 2002/03 the Water Bureau absent any public process or regulatory requirement installed grillwork for floating reservoir covers at the Washington Park reservoirs. The Water Bureau also installed a white liner on the upper Washington Park reservoir, which was intended to last 25 years as represented by an onsite PWB engineer at the time. In a February 19, 2003 powerpoint to City Council referring to the "Washington Park Solution" of covers the Water Bureau said that this "eliminated regulatory modification" and that the "historic structures are not affected" , "trees remain in place", and "roads remain open." The cover material (Hypalon) intended to attach to the installed grillwork was purchased by the Water Bureau but never installed as the 2004 Reservoir Panel did not support the Water Bureau. When the 2004 *Independent Reservoir Panel* did not support "treating or covering" Portland's open reservoirs (the PWB's arguments failed to hold water) and City Council ordered the Water Bureau to terminate covering the Washington Park reservoirs, the Water Bureau attempted to sell the hypalon cover on E-Bay where a Water Bureau employee attempted to purchase the cover at a price well below its value. Commissioner Saltzman stopped the sale but the final disposition of the cover has remained hidden. The grillwork remained in place at the Washington Park Reservoirs 3 and 4. The estimated cost of replacement of the floating covers would be somewhere in the vicinity of $1 million compared to demolition and replacement costs that could reach $100 million. Installation of these covers would meet the regulatory requirements
   While covering the reservoirs was absolutely not supported years ago for many reasons, including the fact that the option of a "risk mitigation" option was included in the draft 2003 regulation, it is still not ideal. This option meets regulatory requirements and would provide opportunity for the Congressional delegation to work in support of revising the poorly crafted LT2 rule such that "risk mitigation" is again an option. In that the compliance deadline for Washington Park is over 5 years away, the covers might never need be installed if the "risk mitigation" option is restored as has been requested by New York's water department and others. Oregon delegation members have indicated that

RESPONSE:

The goals of the Comprehensive Plan are not supported by this plan- see additional comments above.

Economic and Sustainability and public health goals are not met with this demolition plan.

Significant investments have been made in upgrades at the Washington Park reservoirs between 2003 and 2010. The significant costs associated with these consultant and construction contracts will be born by ratepayer over a 25 year period with those costs increasing over time. Many of the upgrades were designed to keep the reservoirs safely operating for an 50 additional years. The majority middle class ratepayers cannot afford any further rate increases on top of rate increases that have been staggeringly high since 2004. The Water Bureau plans another 7% increase in water rates this May.

The open reservoirs avoid new and unique public health risks associated with burying Portland's open reservoirs, for example cancer-causing Nitrification, a problem EPA has long scientifically documented with buried storage. EPA acknowledged in their Coliform Rule papers that they failed to address the Nitrification problem when promulgating the LT2 regulation. Radon, from Portland's secondary lower quality source, the Columbia South Shore Well Field, which presently vents through the open reservoirs will not be able to vent adequately with the elimination of open reservoirs. Radon entering homes via water will permeate homes every time water is used for any purpose.

The historic character of these resources cannot be replaced. The water system, the park, the surrounding neighborhoods and the City will be harmed.

On June 21, 2006 Historian, Park Board Member, the former chair of the Tabor "What goes on Top" committee, Chet Orloff ,wrote to Portland City Council praising them for reconsidering their earlier decisions on the open reservoirs. He additionally suggested "greater historical interpretation of the reservoirs with some permanent, on-site exhibit boards mounted adjacent to them, presenting information and images about the history of the reservoirs , the story of our great water system.. to " more thoroughly inform citizens and deepen everyone's pride in, these great assets."The Water Bureau ignored Chet Orloff's suggestions not wanting to promote the historic resources as the significant assets to our water system and city that they have been for over 115 years.

DENY THE PERMIT

The Historic Landmark Commission should deny this application as it does not meet the criteria for approval.

MITIGATION: Approval of any alteration to the open reservoirs, including the unconsidered options of installation of the floating covers to the grillwork or installation of UV radiation bulbs, should include a mitigation plan that requires completion within the next 3 years of the short-term maintenance projects outlined in the **2010 Robert Dortignacq Washington Park Historic Structures Report** submitted for the record via separate electronic communication. All restoration and maintenance projects recommended in this Historic Structures Report should be mandated by the Historic Landmark Commission to be completed over a reasonable timeframe to suport preservation.

WHEREAS, Portland's open drinking water reservoirs and surrounding structures hold significant aesthetic and historic value to park neighbors and visitors; and

WHEREAS, two separate security vulnerability assessments of the Portland water system indicate that Portland's open drinking water reservoirs are among the most vulnerable points in the water system to contamination both incidental and intentional.

NOW THEREFORE, BE IT RESOLVED, that the City Council accepts the report and recommendations of the Mt. Tabor Open Reservoirs Independent Review Panel; and

BE IT FURTHER RESOLVED, that the City Council directs the Water Bureau to terminate all current contracts for services related to the burial of the Mt. Tabor open reservoirs; and

BE IT FURTHER RESOLVED, that the City Council directs the Water Bureau to work with Portland Parks and Recreation, the Police Bureau and members of the public representing commercial and residential ratepayers, neighbors and stakeholders, to develop and submit to the appropriate state or federal regulator agency a risk mitigation proposal for the City's open finished drinking water reservoirs after the LT2ESWTR is promulgated in final form using a process consistent with the City's adopted Principles of Good Public Involvement; and

BE IT FURTHER RESOLVED, that should the risk mitigation plan submitted fail to gain the regulatory approval of the appropriate state or federal regulatory agency, the City Council, with full public participation and input, will evaluate and decide on appropriate alternative actions to meet the regulatory requirements for open finished drinking water reservoirs in the LT2ESWTR; and

BE IT FURTHER RESOLVED, that the City Council directs the Water Bureau to develop and submit to Council, as part of its 2005-06 capital improvement plan, a schedule for addressing priority deferred maintenance needs at the City's open reservoirs until the City achieves compliance with the final LT2ESWTR through either risk mitigation or alternate means; and

BE IT FURTHER RESOLVED, that the City Council directs the Water Bureau to cease installation of the temporary floating covers on the Washington Park open drinking water reservoirs until promulgation of the final LT2ESWTR and further direction from Council regarding how the City will comply with the regulatory requirements for the reservoirs at Washington Park; and

BE IT FURTHER RESOLVED, that the City Council directs the Water Bureau immediately to implement the phase 1 enhanced interim security measures and deferred maintenance for Portland's open finished drinking water reservoirs described in Exhibit "A" attached to this resolution; and

BACKING SHEET INFORMATION

AGENDA NO. 876-2004

ORDINANCE/RESOLUTION/COUNCIL DOCUMENT NO. 36237

COMMISSIONERS VOTED AS FOLLOWS:		
	YEAS	NAYS
FRANCESCONI	X	
LEONARD	X	
SALTZMAN	X	
STEN	X	
KATZ	X	

Moore-Love, Karla

From: Suzanne Sherman <suzanne@fatcathatsandsacks.com>
Sent: Thursday, April 23, 2015 4:06 AM
To: Council Clerk – Testimony
Subject: Do Not Demolish the Washington Park Reservoirs

Good Day,

I am unable to attend today's meeting regarding the plan to demolish the Washington Park Reservoirs and so I am writing instead to voice my opposition. I am a Mt Tabor resident and have formally testified against the disconnection of the reservoirs here in Mt Tabor Park...and I oppose the dismantling of our reservoir system entirely. It is a costly and unnecessary project...and has proceeded with a lack of proper public input. I completely trust the reservoirs to provide safe drinking water and I am concerned that a closed system will bring on more chances for contamination. In respect to the reservoirs at Washington Park I believe there are better answers than demolition to upgrade and maintain these structures...and I ask that you save the reservoirs and stop the unnecessary project of closing the system.

Thank you,
Suzanne Sherman
Mt Tabor resident

Sent from my iPad

Moore-Love, Karla

From: Kate & Chris <samsa@pacifier.com>
Sent: Thursday, April 23, 2015 3:38 AM
To: Council Clerk – Testimony; Moore-Love, Karla
Subject: Outstanding Uniform Record Request on Material Issue Before Council--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm
Attachments: 2015-01 My Unanswered Uniform Public Records Request and Exchange with Tim Hall.pdf

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

Please let the record in the above case show that my good-faith request for a copy of Portland's LT2 compliance agreement with the Oregon Health Authority remains outstanding to date, even though City staff were fully aware that the document is material to the reservoir land use cases under consideration, given that the document is cited as the fundamental justification for the proposed work in this land use case.

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

CITY OF PORTLAND
UNIFORM PUBLIC RECORDS REQUEST FORM

Date of Request: 1/10/2015

Sent to: Auditor's ofc
ATTN: Toni Anderson
& City Attorney
ATTN: Kin Sheath

REQUESTOR INFORMATION

Name: Katherin Kirkpatrick

Mailing Address: 1319 SE 53rd Avenue

City, State, Zip: Portland, OR 97215 Daytime Phone: 503-232-8663

E-mail Address: samsa@pacifier.com Fax: _____

Preferred method of contact: ○ Mail ○ Phone ☒ E-mail ○ Fax

REQUEST DETAILS

1. Is this request related to a lawsuit involving the City of Portland? land use proceeding

   If "yes," enter the case name, court docket number, or other identifying information:
   LU 14-218444 HR EN, PC #14-118276

2. Is this request related to a tort claims notice involving the City of Portland? No

   If "yes," enter the claimant's name and, if known, the incident date:

3. If you answered "yes" to question 1 or question 2, are you making this request on behalf of a party in the lawsuit or tort claim? on behalf of interested citizens effected by the land use

   NOTE: If "yes," enter "City Attorney's Office" for question 4 in addition to any other applicable bureaus. This is required by state law (ORS 192.420(2)(a)).

4. Bureau or office, if known (a copy of this form must be submitted to each):
   City Attorney's Office

5. A fee reduction or waiver may be possible if the custodian determines that this request is primarily in the public interest. Does this request primarily benefit the general public? Please explain.

   This primarily benefits the public interest as I am seeking this info as part of my attendance at public hearings regarding the fate of Portland's drinking water and will share the info both all other interested citizens via social media, including with the nonprofit public interest foundation Friends of Reservoirs.

6. Does this request pertain to personnel records? No

NOTE: If "yes," please attach a signed release from the employee.

7. How would you prefer to have this request fulfilled?

- ○ I would like to inspect the records.
- ⊗ I would like electronic copies made and sent to me.
- ○ I would like photocopies made and sent to me.
- ○ I would like photocopies made and held for me to pick up.

DESCRIPTION OF RECORDS REQUESTED

Please include the following when describing the materials requested, to the extent known and with as much detail as possible:

- Type of document
- Date
- Author
- Title
- Address of any real property at issue
- Subject matter

NOTE: Additional sheets may be added if necessary.

Description:

- Copy of all municipal resolutions in which Council resolved to decommission the Tabor and/or Washington Park reservoirs.
- Copy of all municipal resolutions in which Council revised, revoked or rescheduled its plan to decommission the Tabor and/or Wash. Pk reservoirs.
- Copy of Compliance Agreement between City of Portland and federal and/or state regulators, setting the date(s) for decommissioning the Tabor and/or Wash Pk reservoirs.
- Copy of all subsequent revised compliance agreements re the same.
- Copy of all municipal resolutions resolving to enter into and/or amend the same.
- Dates unknown but estimated between Spring 2003 and 3/27/2009.

- The City will respond to your request as soon as practicable and without unreasonable delay.
- If the estimated costs involved in fulfilling your request exceed $25, the City will advise you of those costs and require your approval before beginning work.
- If the fee estimate exceeds $100, a 50% deposit may be required to begin work.
- Full payment of the total amount of costs incurred is required before the public records may be inspected or copies released.
- NOTE: Police reports cannot be obtained through the use of this form. For these records, please contact the Police Bureau.

I HAVE READ AND AGREE TO COMPLY WITH THE ABOVE CONDITIONS, and further agree to pay the cost of fulfilling this Public Records Request according to the conditions set forth above. These costs may include the cost of searching for records, reviewing records to redact exempt material, supervising the inspection of records, copying records, certifying records, and mailing records. I agree to pay a maximum of $25 without further approval.

[signature] 1/10/2015

Signature of Requestor Date

Kate & Chris

From: "Kate & Chris" <samsa@pacifier.com>
Date: Sunday, January 11, 2015 4:07 PM
To: <toni.anderson@portlandoregon.gov>; <kim.sneath@portlandoregon.gov>
Attach: 2015-01-11 Katherin Kirkpatrick City of Portland Uniform Public Records Request Form.pdf
Subject: Uniform Public Records Request Form, Citizen Katherin Kirkpatrick

Hello. Please find attached a PDF of my Uniform Public Records Request Form, which is also being sent with original signature via regular mail.

Expedited service and fee waiver/reduction would be much appreciated, as I am a disabled volunteer, the requested documents are not voluminous, and this pertains to the ongoing public hearings regarding the fate of Portland's open-reservoir drinking water system.

I am seeking:

1. Copies of the municipal resolution(s) in which Portland City Council resolved to decommission the Mt. Tabor and/or Washington Park open reservoirs.

2. Copies of any municipal resolution(s) in which Portland City Council revised, revoked or rescheduled the resolution(s) described in #1.

3. Copies of any compliance agreement(s) entered into between the City of Portland and the US Environmental Protection Agency and/or the Oregon Health Authority setting the deadline(s) for decommissioning the Mt. Tabor and/or Washington Park open reservoirs, pursuant to the Long-Term II Enhanced Surface Water Treatment Rule of 2006 ("LT2") and/or the state equivalents of LT2 (including but not limited to ORS 448 and/or OAR 333-061) enacted after state authorities overtook enforcement of LT2 from the federal government in approximately 2009.

4. Copies of any subsequent revision(s) to the compliance agreement(s) described in #3.

5. Copies of any municipal resolution(s) in which Portland City Council resolved to enter into the compliance agreement(s) described in #3 and #4.

Firm dates are not known, but I estimate the date range for the municipal resolutions to be spring 2003 to summer 2009, and the date range for the compliance agreement(s) to be 3/25/2009 to present. I estimate that the records sought consist of a handful of short documents. If the compliance agreement(s) append more than 10 pages of exhibits/attachments, I am happy to accept the main agreement(s) sans exhibits/attachments.

Please let me know if you have any questions or anticipate any problems in complying with my request.

Sincerely,

Katherin Kirkpatrick

Concerned citizen and Mt. Tabor resident
1319 SE 53rd Avenue
Portland, OR 97215
503-232-8663
samsa@pacifier.com

Kate & Chris

From: "Kate & Chris" <samsa@pacifier.com>
Date: Thursday, January 15, 2015 10:49 PM
To: "Hall, Tim" <Tim.Hall@portlandoregon.gov>
Cc: <amanda@portlandoregon.gov>; <nick@portlandoregon.gov>; "Stephanie Stewart" <stewartstclair@gmail.com>; "John Laursen" <john@press-22.net>; <floy21@msn.com>
Subject: Re: Public Records Request (Mt. Tabor decommissioning compliance agreement and related municipal resolutions)

Hello, Mr. Hall. Thank you for your response.

As mentioned, this is not a significant search; I'm requesting a handful of documents whose whereabouts should be easily identifiable by City Council.

If it helps, the original resolution was probably numbered 1011-2003 and dated 9/3/2003; and the original Compliance Agreement was probably signed on about 3/27/2009. If there have been any amendments, they too would be identifiable by City Council.
The documents should be close at hand, because they're the basis of the City's current land use application to decommission the historic Mt. Tabor reservoirs. Commissioners Fish and Fritz frequently reference them in public forums, so for expediency's sake I'm asking the Commissioners by copy of this e-mail to kindly supply you with the dates of the originals and any amendments.

As I hope I made clear, the purpose for my request is to provide these documents to the Historic Landmarks Commission on the Mt. Tabor case, because it appears that the City has neglected to do so. I feel that the public would be served by entering these documents into the case record, given that these documents are the basis on which the City rests its contention that the applied-for work must be done. I'm a disabled citizen on a limited income and have done all my case research on a volunteer basis. I have nothing to gain personally from this request. I would therefore appreciate reconsideration of the public-service fee waiver, or at least an explanation as to why my request would not qualify.

Thank you,

Katherin Kirkpatrick
samsa@pacifier.com

cc: Commissioners Fritz and Fish
Historic Landmarks Commission
Mt. Tabor Neighborhood Association
Friends of the Reservoirs

From: Hall, Tim
Sent: Tuesday, January 13, 2015 11:27 AM
To: mailto:samsa@pacifier.com
Subject: Public Records Request

Hello Ms. Kirkpatrick,

The City Attorney's Office has forwarded your request for documents to me in the Water Bureau.

As you know, this is a significant document search and will take time. Per the City's public records procedures, I will submit to you an estimate of the cost to reimburse bureau staff who must be taken off their regular duties to conduct the search, which includes to determine what documents do exist.

You will be required to pay 50% of the reimbursement cost before the bureau will begin the search, and the other 50% paid once the search is completed. I'm sorry, but your request is not eligible for a waiver.

Let me know if you have any questions.

Thank you.

Tim

Tim Hall
Manager, Public Information & Involvement
Portland Water Bureau
1120 SW 5th Avenue, 6th Floor
Portland, OR 97204
503-823-6926 - Office
503-381-0056 - Cell 24/7

Moore-Love, Karla

From:	Kate & Chris <samsa@pacifier.com>
Sent:	Thursday, April 23, 2015 3:11 AM
To:	Council Clerk – Testimony; Moore-Love, Karla
Subject:	Friends of Reservoirs and Jeff Boley letters--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm
Attachments:	2015-04-19 Friends of Reservoirs open letter to Mayor and Council.pdf; 2015-03-19 Boly Letter to HLC re Failure to Meet Dev Standards of Demo Review.pdf

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

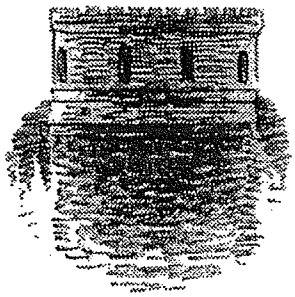
STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

If they have not already been entered, please accept into the above record the attached documents, the 4/19/2015 letter to the Mayor and City Council from Friends of the Reservoirs; and the 3/19/2015 letter to the Historic Landmarks Commission and Bureau of Development Services from Jeff Boly.

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com



FRIENDS *of the* RESERVOIRS

Citizens joining to protect Portland's historic reservoirs and water system

3534 S.E. Main Street, Portland, OR 97214 www.friendsofreservoirs.org

www.lists.pdx.edu/mttabor

April 19, 2015

Sent by e-mail 4/19/2015

Mayor Hales and Commissioners

1221 S.W. 4th Ave.

Portland, OR 972014-1926

Dear Mayor Hales and Commissioners Fish, Fritz, Novick and Saltzman,

While the Portland Water Bureau has written many bad chapters over the last several decades related to their pursuit of highly controversial, costly and unnecessary reservoir and treatment plant engineering projects, there remains an opportunity for City Council to write a much better end chapter – **an opportunity to support community interests over corporate interests.** City Council can immediately put on hold the current Mt. Tabor reservoir disconnection project and the Washington Park reservoir demolition project.

As you know, in light of Senator Chuck Schumer's success with forcing the EPA to include LT2 review and revision as part of EPA's compliance with Obama's Executive Order 13563 (requiring agencies to review, revise and repeal onerous regulations), EPA has committed to complete their LT2 review and revision by the end of 2016. We offer a multi-pronged approach such that the community can see the result of EPA's LT2 review and revision before any unnecessary "cutting and plugging" of pipes takes place

at Mt. Tabor and before City Council takes any Land Use steps to support demolition of the historic and fully functional open reservoirs at Washington Park.

The first prong of this new approach would be to work with the Oregon Health Authority (OHA) to approve a "temporary" disconnection of all of the Mt. Tabor reservoirs, thus meeting the Water Bureau's self-imposed December 2015 Tabor compliance deadline, and avoiding the unsupported and degrading "cutting and plugging" of pipes throughout Mt. Tabor park. The OHA has already approved (5 years ago) a "temporary" disconnection of a Tabor reservoir, allowing the Water Bureau to keep Tabor's Reservoir 6 offline since September 2010 . A similar "temporary" disconnection of all of the reservoirs at Mt. Tabor would not only avoid all of the "cutting and plugging" of pipes throughout the park but would also provide opportunity for Oregon's Congressional delegation to join forces with Senator Schumer and others to reinstate the "risk mitigation" reservoir compliance option included in the draft EPA LT2 rule but inexplicably removed from the "onerous" final rule. Senator Merkley has advised community stakeholders many times that he would join forces with Senator Schumer and others, if Portland City Council secured a deferral or other such alternative.

Concurrently, Portland would collaborate with the Oregon Health Authority to secure a deferral of the Water Bureau's self-imposed time line of compliance with LT2 reservoir requirements. As confirmed by the Oregonian, our new Governor has asked the Oregon Health Authority to review the community request for a deferral, but as we know, there will be no further supportive action without the active support of the Portland City Council.

A Friends of the Reservoirs public records request of OHA's documents and communications related to Commissioner Novick's 2013 reservoir deferral request revealed that:

1. David Leland confirmed in an internal email that there is no limit to the number of times a request for deferral can be made.

2. The Portland Water Bureau failed to provide necessary supportive documents to back up Commissioner Novick's deferral request.
3. The Portland Water Bureau used a surrogate to send the message to OHA that they wanted to proceed with build projects. Dave Leland stated, "... now we know what the Water Bureau wants." (This messenger is the same person Mayor Katz publicly chastised at the 2004 Reservoir Panel Council meeting when that person admitted to anonymously contacting the Urban League member at the end of the 3 months of panel work.)
4. There was no proactive collaboration between the City of Portland and OHA, as was the case between the Rochester water department and their health authority when Rochester successfully secured a 10-year deferral of their low-cost compliance plan for their 1876 open reservoirs, which are also set in city parks. Portland failed to engage in any follow-up advocacy or lobbying to secure a deferral such as Rochester's. A relevant aside to this point is that even if the EPA fails to revise the onerous unsupported requirements, Rochester plans on retaining their historic open reservoirs as functional open reservoirs spending but $22 million to add UV bulbs, which makes clear that lower costs options exist if the utility works in service of community interests.

We request that the Portland City Council direct the Portland Water Bureau to prepare a deferral request that will succeed. The City must then advocate for success and collaborate with OHA, engaging the support of our Governor such that the decision is not made by low level OHA bureaucrats. OHA internal communications revealed that then Director Goldberg was supportive of finding alternatives to enforcing the fast-track compliance schedule, but Dave Leland, who led the decision-making process was not. With a deferral the Congressional delegation can then join forces with others to ensure that the revised EPA LT2 rule reinstates the "risk mitigation" option and that *Cryptosporidium* sampling distinguishes the majority harmless species from the few harmful species.

With regard to the demolition of the Washington Park reservoirs, the current process has not fulfilled the Demolition Land Use requirement "*...that there is an opportunity for the community to fully consider alternatives to demolition.*" The community has never been afforded a meaningful opportunity to fully consider the multiple alternatives to demolition of the Washington Park reservoirs, a project that is scheduled to last for four years. Further, Council Resolution No. 36237 requires that stakeholders be brought together utilizing the *City's adopted Principles of Good Public Involvement* **in any *actions related to the open reservoirs*.** The Water Bureau has explicitly defied this Council ordinance. At the March 30, 2015 Historic Landmark Commission (HLC) meeting the PWB lead engineer on this project refused to respond to a member's question as to why the unneeded storage wasn't being built elsewhere. As explained by the Water Bureau to the HLC, the current project will result in four years of zero water storage at Washington Park. This HLC member expressed that clearly, there is no reason to demolish these significant historic assets.

LT2 compliance can be achieved in alternate ways. A new *Independent* Reservoir Panel should be convened, one that does not exclude stakeholders such as Friends of the Reservoirs, to fully consider the many alternatives to demolition. Fully preserving the well functioning and irreplaceable reservoirs at Washington Park preserves Portland's heritage, beautifies the city, enhances civic identity, and supports economic vitality by recognizing and maintaining the significant recent investments made at the reservoirs and by avoiding the waste of the $80 million associated with demolition and construction.

We implore the City Council to support and take immediate action on our request to put these two massive projects on hold and pursue these recommendations so that there will be a better ending to this decades long struggle between our City administrators and the citizens and ratepayers of Portland. We suggest meeting to discuss further and please contact us with any questions.

Sincerely,

Floy Jones on behalf of
Friends of the Reservoirs

March 19, 2015

Hillary Adam
Land Use Services
Bureau of Development Services
1900 SW 4th Avenue
Suite #5000
Portland, OR 97201

Re: LU 14-249689 DM (PC# 14-139549)
Demolition Review for Washington Park Reservoirs #3 and #4 and the Weir Building

Dear Ms. Adam:

I was on the Board of the Arlington Heights Neighborhood Association from 1998 until one year ago and for most of that time I was its president. In that capacity I believe I was more involved with the Reservoir preservation effort than anyone else on the west side. I assisted Cascade Anderson Geller in the preparation of the Washington Park Reservoirs application for historic monument status.

In my opinion the city will be unable to carry the burden of proof on the easiest approval criterial available, namely that **"Denial of a demolition permit would effectively deprive the owner of all reasonable economic use of the site."** Portland Planning and Zoning Code 33.846.080 C. 1. Demonstrating effective deprivation of all reasonable economic use of a site is a very high bar. The city cannot even come close to clearing it.

The city apparently and erroneously assumed the following as facts: 1) that the LT2 mandate regarding drinking water now and forever precludes reservoirs 3 and 4 from serving as storage for all water of any type; 2) that Congress will never repeal nor modify LT2; 3) that it need not consider an impending category 9 earthquake, where the outcome is unknown and therefore renders destruction of existing backup resources recklessly irresponsible, because either reservoir 3 or 4 or both may survive that earthquake; and 4) that there are alternatives to the demolition proposal, which are vastly less expensive, but easily implemented and are therefore more economically feasible than the proposal.

LT2 is political action based on questionable science. If after a category 9 earthquake either reservoir 3 or 4 or both were the only ones functioning, is there any question that Congress would prefer to have the emergency option of repealing LT2 to that of rebuilding another tank, and that this reasonably foreseeable possibility gives these resources economic utility?

The primary false assumption is that the only way to supply LT2 compliant water to the west side is by building a tank that is within the footprint of the current reservoir #3 and then constructing a new aesthetic amenity above it. There are two obvious alternatives that would cost tens of millions less and yet function as well as the proposal.

The first alternative is to simply take advantage of the #3 reservoir grillage that was installed in 2004. All that would be needed is to purchase a new cover. Since the city committed to this alternative over ten years ago as compliant with LT2, it can hardly argue now that installing a floating cover over reservoir #3 is not a "reasonable economic use of the site."

The second alternative is to use the same strategy on the west side that was implemented on the east side. On the east side the city appropriated a mountain many miles from the existing Mt. Tabor outdoor reservoirs to contain LT2 compliant water. On the west side there is a soccer field only a few hundred feet to the south of reservoir #4, which could be excavated for the new underground tank with the soccer field rebuilt on top.

This alternative is not only tens of millions less expensive than the proposal, but far easier to implement and spares the Historic Monuments. Obviously, the viable opportunity to continue only aesthetic use of the existing reservoirs and so avoid the extreme cost of replicating their historic and artistic value destroys the city's contention that demolition of the reservoirs is an economic necessity.

Some interested parties have the impression that the city is committed to rebuilding a replica of at least the existing reservoir 3 on top of the new tank. If that obligation is supposed to be in the proposal its actual text is to the contrary.

To be meaningful a commitment to restore must include detailed architectural plans, engineering studies, and a budget with guaranteed financing. Otherwise, the city is offering a substitute for the preservation benefits assured in Chapter 33.846, which like the reservoirs themselves are set in stone, in exchange for the vague promise of "a below-ground reservoir with a tiered reflecting pool in the same location and approximate footprint as the existing Reservoir 3 and a reflecting pool and stormwater swale in the location as the existing Reservoir 4 but with a reduced footprint."

Significantly the proposal seeks "to remove three contributing resources (Reservoirs 3 and 4 and the Weir Building) from the Washington Park Reservoirs Historic District." It makes no proposal for modification of the existing structures, but rather calls for their removal, that is demolition.

In conclusion the city has not and cannot demonstrate compliance with Planning and Zoning Code 33.846.080 C. 1. Moreover, the city does not even offer to attempt to replicate the protected artistic and historic features of these treasures. The proposal is facially flawed.

Sincerely,

Jeffrey E. Boly
2879 SW Champlain Drive
Portland, OR 97205-5833
Home 503-223-4781; Mobile 503-381-6492
jeff@jeffandlinda.org

Moore-Love, Karla

From: Kate & Chris <samsa@pacifier.com>
Sent: Thursday, April 23, 2015 2:57 AM
To: Council Clerk – Testimony; Moore-Love, Karla
Subject: Fernandez Paper re Open Reservoir Benefits--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm
Attachments: 2014-05 Fernandez Waiver Basis.pdf

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

Please accept into the above record the attached document, "The Scientific and Public Health Basis to Retain Open Reservoir System for the City of Portland, Oregon.

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

SCIENTIFIC and PUBLIC HEALTH BASIS to

RETAIN OPEN RESERVOIR WATER SYSTEM

for the CITY OF PORTLAND, OREGON

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Request for Waiver from the U.S. EPA Long Term 2

Enhanced Surface Water Treatment Rule (LT2)

Regarding Covered Reservoirs

"Science will determine the ultimate outcome."
–EPA Administrator Lisa Jackson, August 2011
letter to U.S. Sen. Charles E. Schumer (D-NY) acknowledging
his request for an "LT2 Rule" reservoir waiver

"We're just trying to get at the public health impacts and if there's a better way to do that we'll be wide open to it."
–EPA Administrator Gina McCarthy, April 2014
Congressional testimony response to U.S. Rep. Eliot Engel's (D-NY)
question about the status of New York City's reservoir waiver request

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By Scott Fernandez
M.Sc. Biology / microbiology & water chemistry

May 2014

www.bullrunwaiver.org | bullrunwaiver.org@gmail.com

Preface

Scientific accuracy is of utmost concern when determining the best system for treatment and storage of Portland's water supply. However in recent years public officials and some of the media have framed decisions affecting the city's water policy around opinion and expediency instead of sound science and engineering.

Far from being merely an "aesthetic" issue affecting Mt. Tabor and Washington parks, open reservoirs are of critical importance to drinking water quality and public health for every Portland resident. This paper addresses the urgent need to clear up confusion surrounding the vital public health component of open reservoirs for maintaining Portland's record of exceptional municipal water quality and will show that:

- City Council's push to cover Portland's open reservoirs – before the Environmental Protection Agency (EPA) completes its "LT2 Rule" review and waiver process in 2016 – will create more public health problems for residents than it solves.

- Unlike in other cities, Portland's water supply from the federally protected Bull Run watershed is not at-risk from sewage based microorganisms such as "Cryptosporidium" – which the EPA's blanket "LT2 Rule" is meant to address.

- Covering Portland's reservoirs will carry risk from enabling toxic and carcinogenic contaminants such as radon, chloroform and other disinfection chemical byproducts to accrue in the water supply in addition to nitrification, lack of oxygenation, and absence of sunlight.

- There are demonstrable public health benefits of open reservoirs due to efficient atmospheric volatilization, chemical biodegradation, and broad-spectrum sunlight saturation that reduce and eliminate contaminants. Portland's open reservoirs can already meet EPA microbial standard and are the most important water quality "barrier" in the Bull Run system. They block contaminants from reaching the downstream distribution system using the scientific principles of chemistry, physics, and microbiology.

- Public officials must preserve Portland's open reservoirs as an essential component of the water system to maintain municipal water quality and protect public health. The basis and merits for communicating effectively with EPA on this matter simply requires coordinated and committed support from Portland City Council, the Oregon Health Authority, Gov. Kitzhaber, and Oregon's Congressional delegation.

Contents

I. EXECUTIVE SUMMARY

The letter and spirit of the EPA drinking water regulation is to provide equal or greater public health benefits. ***A decade of experience under the 1986 EPA Safe Drinking Water Act (SDWA) revealed several areas where responsible, science-based flexibilities and a better prioritization of effort could improve protection of public health compared to the one-size-fits-all approach of the 1986 statute.*** **(EPA 1996)** It will be shown that the chemistry, physics, and microbiology principles of open reservoirs of Mt. Tabor Park and Washington Park will continue to provide safe healthy drinking water for generations to come. The reliable and scientifically-sound approach to unwanted environmental chemicals will be achieved through open reservoirs. Covered reservoirs degrade drinking water quality and increase public health risk through toxic and carcinogenic chemicals progression.

In the past 30 years the Safe Drinking Water Act has been highly effective in protecting public health and has also evolved to respond to new and emerging threats to safe drinking water. Disinfection of drinking water is one of the major public health advances of the 20th Century. One hundred years ago typhoid and cholera epidemics were common throughout American cities; disinfection from chlorine was a major factor in reducing these epidemics.

EPA's "Long Term 2 Enhanced Surface Water Treatment Rule" (LT2) addresses microorganisms which is the primary reason Portland deserves a waiver from the regulation. Because the Bull Run watershed does not have exposure to industrial, agricultural, or municipal sewage, Cryptosporidium, viruses, and other microorganisms become a non-issue in regard to public health risk for water users. In addition, sunlight is a powerful source of natural broad spectrum ultraviolet light (UV) that reduces infectivity of microorganisms. Portland's open reservoirs already meet EPA microbiological standards.

There have been no positives for Cryptosporidium, Giardia, and viral microorganisms in sampling of Portland open reservoir drinking water throughout the 1990's and beyond; in addition to a recent year-long study (AWWA RF 3021) in which the sampling methodologies used were more rigorous in assessment. Furthermore EPA assertions for the basis of LT2 nationwide proved to be incorrect. Cryptosporidium has not had the negative public health impact EPA projected. Scientists have not seen the deaths, widespread outbreaks, or endemic disease identified from Cryptosporidium drinking water public health data around the U.S.

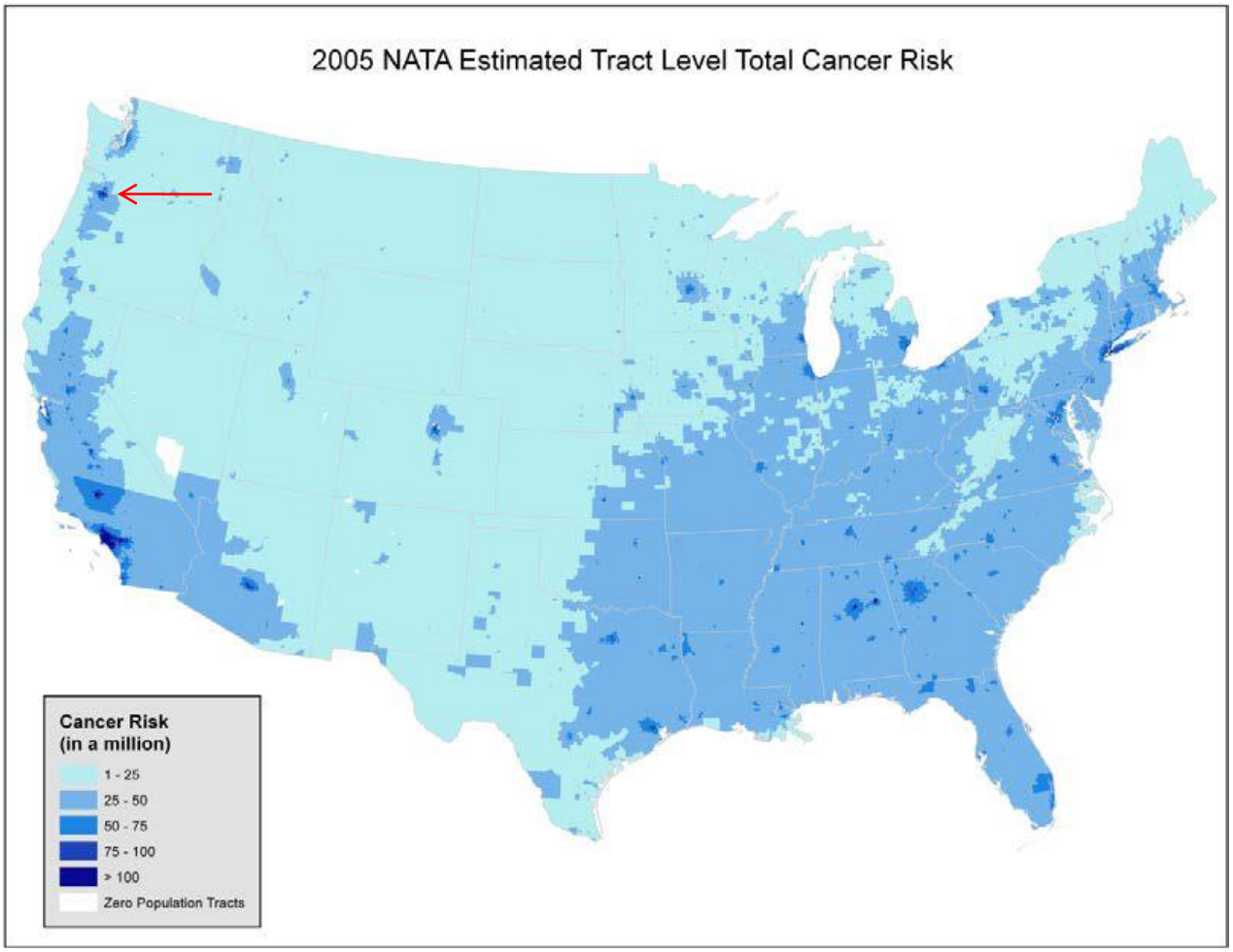
Second, open reservoirs allow for efficient ventilation of toxic gases such as radon.

Third, over the years scientists have learned that chlorine and chloramine can generate many unwanted disinfection byproducts. Open reservoirs address the issue of effectively managing chemical disinfection byproducts using a natural ecosystem, thus providing safer water quality in complete contrast to that of covered reservoirs. Open reservoirs provide safe drinking water by acting as a barrier to toxic and carcinogenic chemicals along with disinfection byproducts by vaporizing, microbial biodegradation, or sunlight break down of molecules.

While critical to maintaining Portland's healthy drinking water system, these scientifically supported public health benefits of open reservoirs have not been recognized by Portland City

Council and the Portland Water Bureau. These open reservoir public health benefits must be recognized as the basis for responsible management of Portland's existing high-quality water treatment and delivery system.

An additional note is that Portland has significant air quality problems. Thirty-five (35) Portland schools were ranked in the bottom 5% in the nation's high toxic hot spots from airborne metals and gases. Covering the reservoirs will not allow the chemical disinfection byproducts and other toxic and carcinogenic gases to vaporize efficiently before entering the water distribution system. These toxic and carcinogenic chemicals will end up being released from drinking water into homes, schools, and workplaces, thus adding to the already present and problematic environmental air public health burden.



Portland ranks in the highest percentile of U.S. cities for toxic air quality cancer risk. Residents, especially children with their lower body weight, are at highest risk from the additional toxic burden of degraded water quality. (See Refs. 1-5)

II. GLOSSARY

AWWA RF – American Water Works Association Research Foundation

CSSW – Columbia South Shore Wellfield located on the Columbia River between the Portland airport and Blue Lake areas. It is the source of our drinking water containing radioactive radon 222.

DBP – Disinfection By-product

pCi – pico Curie- measurement of radioactive material

EPA – United States Environmental Protection Agency

IARC – International Agency for Research on Cancer

LT2 – EPA Long Term 2 Enhanced Surface Water Treatment Rule

NAS – National Academy of Sciences

NDMA – Nitrosodimethylamine, a drinking water disinfectant byproduct that is broken down by sunlight in open reservoirs

NOM – Natural Organic Material, reaction with chlorine and chloramines

OHA – Oregon Health Authority

PAEC – Potential Alpha Energy Concentration

Precautionary Principle – Adopted by Portland City Council in 2006. "When an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." See "Toxics Reduction Strategy: A plan for minimizing use of toxic substances of concern in government operations by using the Precautionary Principle" (http://www.sehn.org/pdf/portland.pdf)

PWB – Portland Water Bureau

Radioactive Chemicals from Columbia South Shore Wellfield –
Bi- bismuth 214, 210 β, Γ
Pb- lead 214, 210, 206 β, Γ
Po- polonium 218, 214, 210 α
Rn- radon 222 α, Γ
(Symbol Key: α-alpha / β-beta / Γ-gamma – forms of radioactive particles)

S2DBP – Stage 2 Disinfection and Disinfectant Byproduct Rule

SDWA – EPA Safe Drinking Water Act

USGS – United States Geological Survey

WHO – World Health Organization

III. INTRODUCTION

Citizens of Portland have been asking City Council to formally request a waiver from the EPA "Long Term 2 Enhanced Surface Water Treatment Rule" regulation for over a decade. We are not alone in requesting this waiver. The City of New York, the New York State Department of Health, and the entire New York Congressional delegation are all requesting a similar waiver for their Hillview open reservoir.(Ref. 6) Portland City Council needs to join the citizens of Portland in pursuit of a scientifically supported EPA open reservoir waiver of the "LT2 Rule."

This paper will review, identify, and demonstrate the superior public health benefits of the open reservoirs at Mt. Tabor Park and Washington Park that covered reservoirs cannot provide. These public health benefits were known over 100 years ago (see sidebar at right). Misinformation presented by the Portland Water Bureau will also be scientifically corrected.

Portland has had safe and healthy drinking water for over 100 years because federally protected Bull Run and the open reservoirs have been the foundation of the multiple-barrier approach to public health. This multiple-barrier approach allows Portland to already meet and exceed EPA regulated contaminant standards. Microbial contaminants have traditionally received more attention from a public health standpoint. Bull Run has no sewage exposures so microorganisms are principally a non-issue. However in recent years there has been a growing concern regarding chemical contaminants present in drinking water that affect public health.

The fundamental principles of sunlight disinfection are well-established. Esteemed epidemiologist Milton J. Rosenau wrote in 1902:

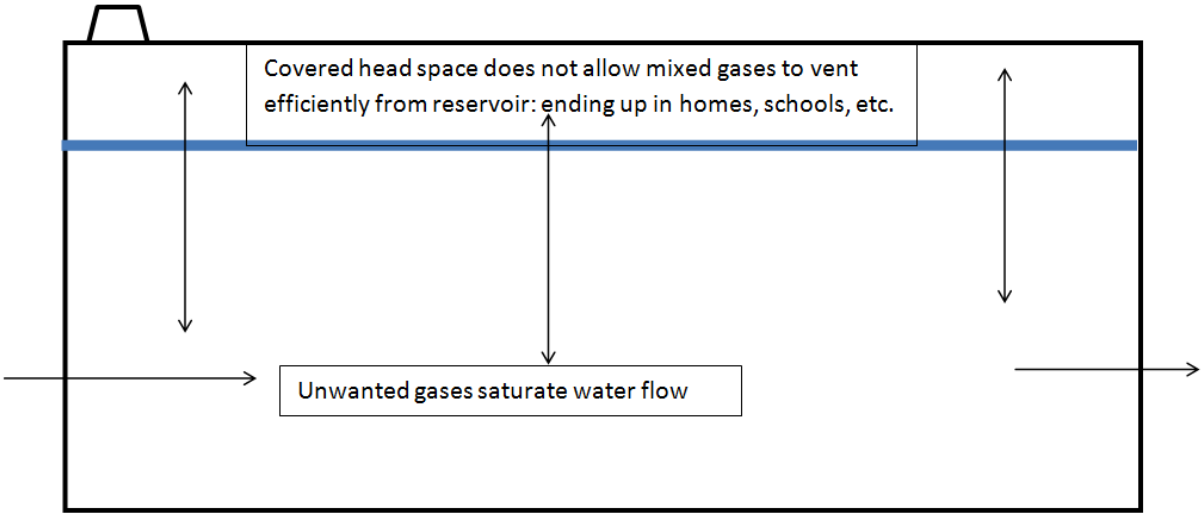
"Sunlight (direct) is an active germicide. It destroys spores as well as bacteria. The importance of the sun's rays in destroying or preventing the development or growth of microorganisms in nature cannot be overestimated. Even diffused light retards the growth and development of microorganisms, and if strong enough may finally kill them. In water or clear solutions it penetrates some distance. The importance of oxygen in the influence of light upon bacteria is emphasized. Bacteria in light, in the presence of oxygen and water, cause a production of hydrogen peroxide which is well known to have strong disinfection powers."

--Milton J. Rosenau, M.D., was commissioned as an assistant surgeon in the United States Marine Hospital Service (now the United States Public Health Service) in 1890. In 1899, he was appointed Director of the Hygienic Laboratory of that service. He was instrumental in 1922 in the establishment of the Harvard University School of Public Health and, in 1940, became first dean of the School of Public Health at the University of North Carolina.

As a community we have challenged the applicability of EPA's LT2 Rule and Cryptosporidium in Portland's drinking water system as a public health problem that does not exist because we don't have agricultural, industrial, or municipal sewage exposures in our Bull Run source water. Cryptosporidium has never been found in our open drinking water reservoirs. Equally important for continued public health, we need to include a discussion of the EPA Stage 2 Disinfection and Disinfectant Byproducts Rule (S2DBP) relating to disinfection byproducts and other unwanted chemicals that our open reservoirs remove from our drinking water. Utilizing the applied natural laws of microbiology, chemistry, and physics we show that our open reservoirs in Mt. Tabor Park and Washington Park provide safe and healthy drinking water superior to water in covered reservoirs. Direct sunlight, oxygenation, an aerobic microbial ecosystem, and the large surface areas of open-air reservoirs allow break down and venting of harmful gaseous chemicals reflecting the functioning of a healthy water system.

A. Adverse effects and public health problems of covered reservoirs

Covered reservoirs cannot effectively remove toxic and carcinogenic gases and other chemicals. Gases such as radon and chloroform remain saturated in the drinking water and they cannot efficiently escape. Because covering the reservoirs creates a drinking water system closed to sunlight and poorly exposed to the atmosphere, these toxic and carcinogenic gases then end up venting in our schools, homes, and businesses. Without sunlight carcinogenic chemicals such as NDMA (Nitrosodimethylamine) are not broken down and bacterial metabolic processes promoting toxic nitrification byproducts continue on unimpeded.



Two (2) small air vents opening combine to ~75 sq. ft. on a ~217,000 sq. ft. ~5-acre reservoir roof such as PWB 9-6-2013 Powell Butte 2. Small vent allows water to move through covered reservoir – otherwise a vacuum would be created and water flow would be restricted. Small air vents are inefficient in removing toxic and carcinogenic gases. The history of U.S. covered reservoirs also documents bird entry through small air vents to roost and contaminate water resulting in human death.

B. Public health benefits of open reservoirs

The Portland open reservoirs provide safe and healthy drinking water by naturally engaging in removal of toxic and carcinogenic disinfection byproducts and other chemicals. It is important to remove these environmental chemical exposures because they are the sources of great health risks, such as lung and other cancers from radon gas and radon progeny of which "there is no safe level of radon exposure." (US EPA) (Refs. 7-14)

Affected organ systems from chloroform include: Cardiovascular (heart and blood vessels); Hepatic (liver); Neurological (nervous system); Renal (urinary system or kidneys); Reproductive (producing children); Developmental (effects during periods when organs are developing). (Refs. 15-16)

Nitrosodimethylamine (NDMA), a drinking water disinfectant byproduct that is broken down by sunlight in open reservoirs, has been classified by the International Agency for Research on Cancer (IARC) as a probable carcinogen for humans (liver cancer). The mechanism by which NDMA produces cancer is well understood to involve biotransformation by liver microsomal enzymes generating the methyldiazonium ion. This reactive metabolite forms DNA adducts, with most evidence pointing to O6-methylguanine as the likely proximal carcinogenic agent. (Ref. 17)

Visionary leaders fought for our Bull Run water source over 100 years ago. **Bull Run source water is federally protected from human entry that is not exposed to industrial, agricultural, or municipal activities.** Portland is fortunate to have very few chemicals in our drinking water. Open reservoirs are efficient in removing the chemicals we don't want to drink or have in our environment. We want chemicals removed because EPA long-term drinking water standards are based only on adults, not considering the extended exposures that increase health risks for younger ages. EPA long-term chemical exposure risk levels are based on 70 kg / +154 lb. adults, not children. (Ref. 18)

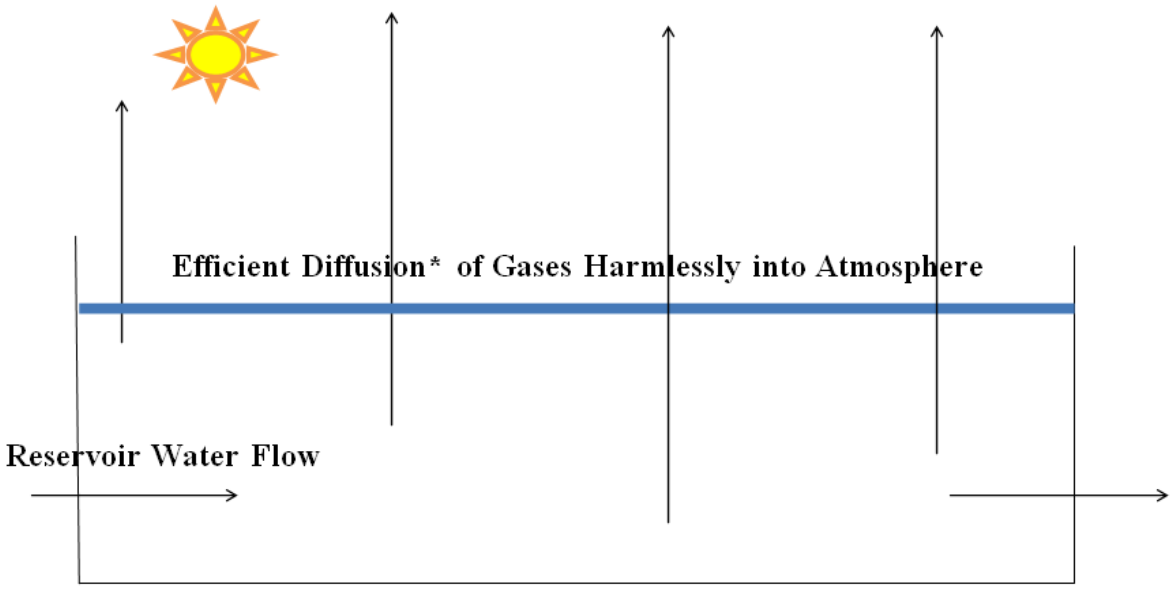
Portland's open reservoirs operate as unique barriers and provide superior efficiencies impeding the movement of toxic and carcinogenic gases and chemicals into the distribution system by utilizing the following scientific principles:

- Atmospheric volatilization of toxic, carcinogenic gases – Radon
- Atmospheric volatilization, Trihalomethanes, (THM) – Chloroform
- Aerobic microbial biodegradation – Haloacetic acids, (HAA5), Stage 2 DBP
- Natural oxygenation – Increases presence of helpful aerobic microorganisms
- Aerobic bacteria – 18x increased oxidative activity v. anaerobic bacteria
- Direct sunlight – Degrades carcinogenic N-nitrosodimethylamine (NDMA)
- Direct sunlight – Inhibits nitrification bacteria and the buildup of nitrites, nitrates and nitrosamines from ammonia disinfection
- Direct sunlight – Oxygen/photons, natural disinfection from oxides

Removing Portland's open reservoirs raises the threat to public health from increased exposure to toxic and carcinogenic chemicals. (Ref. 19)

Portland water users benefit from the environmentally sustainable and effective open air reservoir processes that remove or impede movement of toxic and carcinogenic gases and chemicals from our drinking water system. The "Precautionary Principle" (see Glossary) – the public health policy adopted by Portland City Council in 2006 – applies directly to decisions affecting Portland's water reservoirs. Open reservoirs provide an efficient method of eliminating unwanted drinking water gases such as radon-222 and chloroform through the process of *atmospheric volatilization*. Open reservoirs provide a natural, cost effective, and healthy solution to a recognized public health problem.

Reasons Open Reservoirs Function So Well: Open reservoirs act as a natural barrier to toxic and carcinogenic chemicals, harmlessly releasing them before they enter the drinking water distribution system.



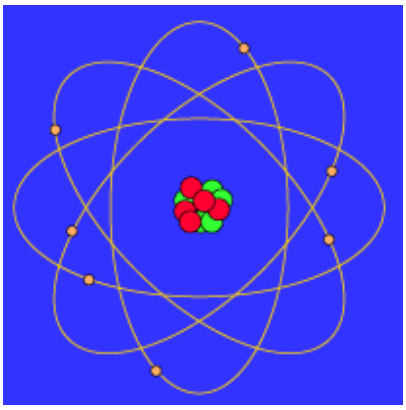
Highly efficient open reservoir chemical movement from water (high gas concentration) to air (low gas concentration) provides the desired natural and harmless removal of chloroform and radon gases from open reservoirs. Open reservoirs keep toxic gases out of water used in homes, schools, and workplaces.

Mt. Tabor Reservoir 6. Open reservoir water oxygenation from fountain and waterfall aeration also removes toxic and carcinogenic gases such as radon and chloroform. Gases escape efficiently through diffusion – the movement of particles from high concentration to lower concentration. Diffusion is enhanced by wind and natural convection in water wave action.

Mt. Tabor Reservoir 5. Open reservoir drinking water inlet: waterfall agitating action aerates water providing oxygen, promotes water movement, while removing unwanted gases. Open reservoir sunlight also provides a public health barrier, using a natural, sustainable, gravity fed carbon-free process delivering safe and healthy water.

IV. FINDINGS: PROBLEMS VS. BENEFITS

A. Radon – Concentration vs. Dissipation



Covered reservoirs are inefficient in allowing escape of radioactive radon and other toxic gases. Open reservoir atmospheric volatilization provides efficient escape of toxic and carcinogenic gases.

Portland's open reservoirs can efficiently vaporize /diffuse radioactive radon-222 gas to the atmosphere using natural aeration. Due to a high Henry's Law constant, radon can leave water on contact with air when agitated. Radioactive radon gas is a serious and widely underestimated health risk that is naturally occurring in soil and groundwater. Portland's drinking water radon gas originates from the Columbia South Shore Well field. Because it is not chemically reactive with most materials it will move freely as a gas and can move substantial distances from its point of origin. Ingestion of radon through drinking water can also contribute to internal organ illness such as stomach cancer once it is absorbed into the blood stream.

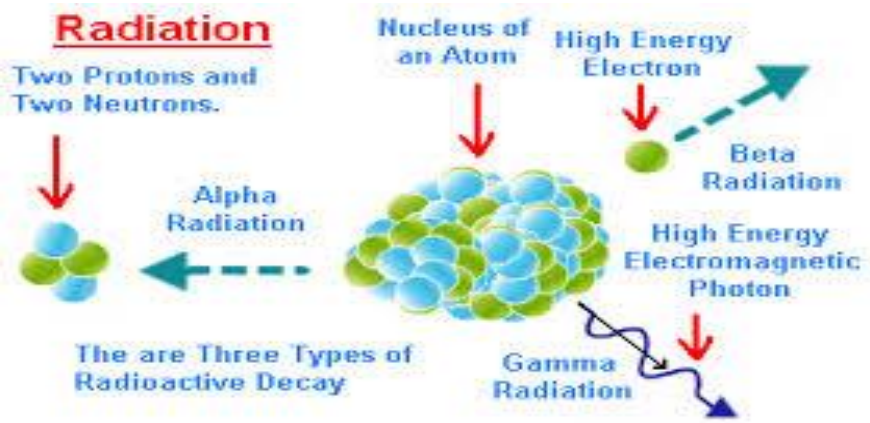
EPA acknowledges there is ***no safe level of radon exposure***, regardless of the source, air or water. The cancer risk of radon in water is higher than cancer risk from any other drinking water contaminant. Radon from drinking water can end up in the air of buildings in several different ways: **substantial radioactive water aerosols** can be created from showering, clothes washing, dishwashing, flushing toilets, and bathing.

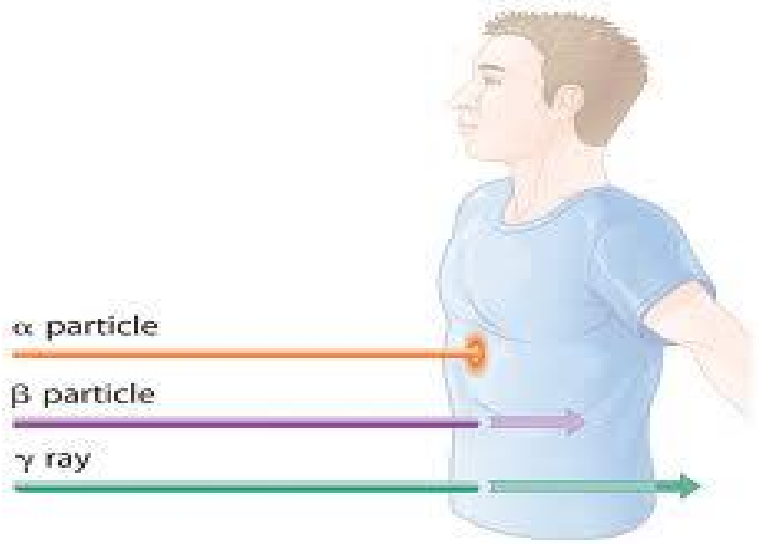
Radon is the second leading cause of lung cancer and contributes to +20,000 deaths each year. Radioactive alpha emitting radon gas also decays into radioactive atoms such as daughter progeny *polonium, lead*, and *bismuth.* These atoms can get trapped in the lungs when you breathe also emitting alpha, beta, and gamma particles continuing to release bursts of energy-damaging cells. This energy can genetically damage lung, blood, and other tissues' DNA. Over time these atomic exposures can lead to lung and other types of cancer. Because ***children have a much higher respiration rate than adults more radon can be inhaled***. EPA danger levels **underestimate** increased risk of radioactive particle inhalation and public health impact expectation in children.

Radon-222 Decay Process contains radioactive isotopes emitting all 3 types: Alpha, Beta, and Gamma particles

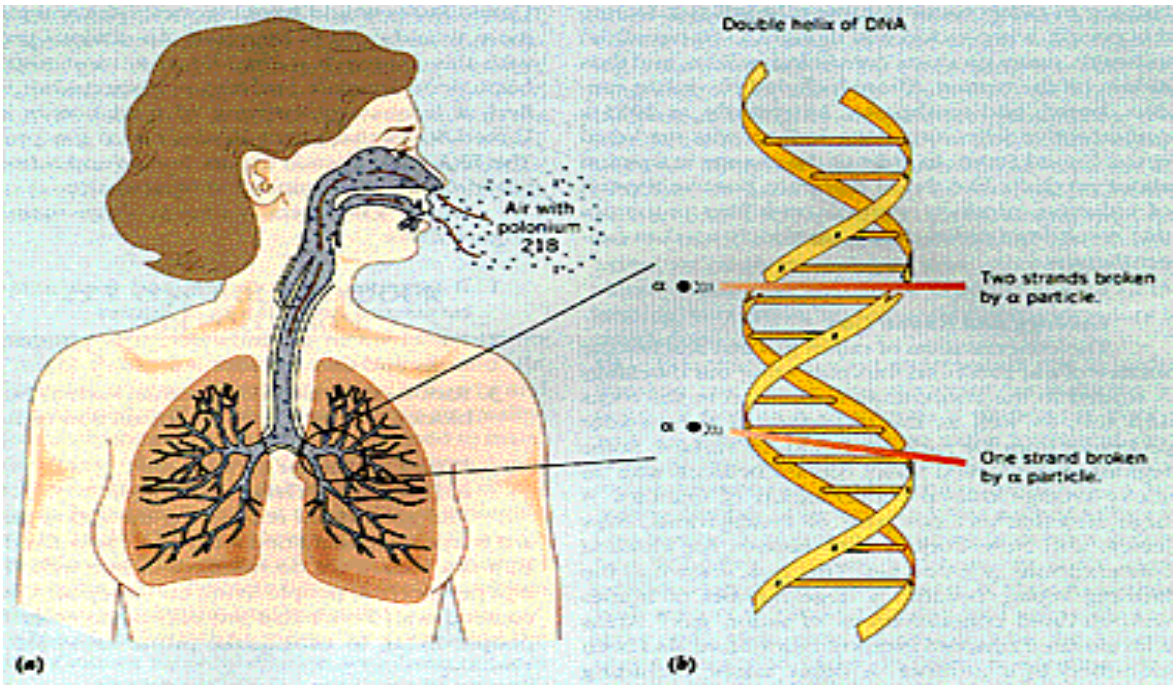
- Radon 222 – alpha particles and few gamma particles
- Polonium 218 – alpha decay
- Lead 214 – beta particles and gamma particles
- Bismuth 214 – beta particles and gamma particles
- Polonium 214 – alpha particles and few gamma particles
- Lead 210 – 22-year half-life so first 5 are basis for effect (Ref. 20)

Radon Isotopes And Decay Particles – Three (3) types of radioactive radon decay particle energy and negative impact on health:

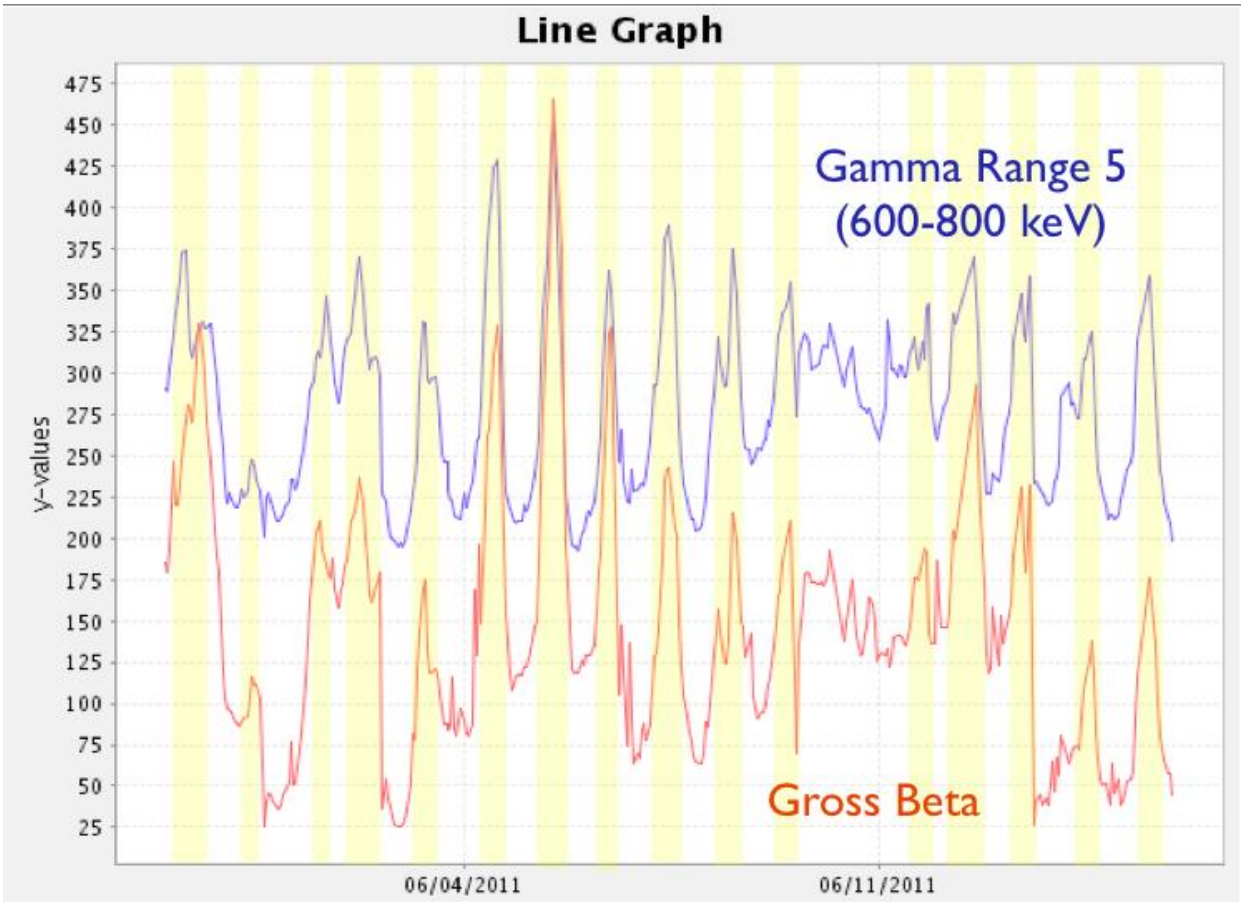




All radon decay particles – alpha, beta and gamma radioactive energy levels – can initiate negative health effects. Alpha particles, i.e., polonium, can penetrate cellular DNA promoting tissue damage and cancers. Beta and gamma particles have *much* higher energy levels that promote greater tissue damage resulting in *increased* health risks.



Radon- alpha particles penetrating cell DNA ending in tissue damage and cancers



Concurrent radioactive beta β and gamma Γ activity from radon 222 progeny

Data from the Oregon Department of Health and Human Services show more than 25% of the homes tested in Multnomah County exceed the soil origin ***indoor air*** action level of 4pCi / liter due to geological conditions. The Portland Water Bureau wrongly downplays the high public health risk of ***any*** level of radon in our drinking water by not acknowledging subsequent inhalation.

In a closed drinking water system without open reservoirs the risk of aerosolized radon inhalation from drinking water increases substantially. ***Any*** level of radon exposure from water would contribute to the total cumulative effect of inhalation risk associated with radioactive indoor air. A 1000 sq. foot house with a 4 pCi / of radon has nearly 2 million atoms in the air decaying every minute in *addition* to the decay atoms of the radioactive progeny such as polonium, etc. (USGS)

One single atom / alpha/ beta/ gamma particle can begin the cancer process when inhaled. Homes in the zip codes 97210- 97213 in north and northeast Portland are especially at risk, and there are many other areas in the city. ***Open air reservoirs provide the most efficient and sustainable radioactive radon risk mitigation process through volatilization***. The open reservoirs use the laws of chemistry and physics; utilizing diffusion up the water column, water agitation at the inlet, wind action promoting diffusion, leading to natural and harmless volatilization free of electricity. (EPA radon map)

The City of Portland Columbia South Shore Well fields (CSSW) produce radon 222 in excess of 300 pCi /L, exceeding the EPA action level. The Portland Water Bureau will tell the community the radon levels are diluted to 10% during summer usage. However if we incur turbidity events excluding Bull Run water we will be using CSSW water with radon 222 gas exceeding recommended levels. This does not include the cancer causing radioactive progeny atoms such as bismuth, polonium, lead, etc., from radon 222 decay. (Ref. 21)

EPA and Drinking Water Radon
EPA does not regulate radon in drinking water. The health concern with radon in drinking water is also associated with everyday household uses that can transfer radon to indoor air throughout the house along with the many radioactive decay isotopes. Radon in water can be released into the air when water is used for showering, laundry, washing dishes, toilet use, and other household activities. Some researchers have estimated that 1 pCi /L of airborne radon will result from the normal use of a water supply containing 10,000 pCi /L. This number is only an average and ***subject to variation***. The amount of radon transferred from water to air is a function of:

- The waterborne radon level;
- The amount of water used;
- The type of water use activity, e.g. shower (high transfer) vs. running water in a sink (low transfer); and
- The water and air temperatures (as the temperature of the water increases, radon transfer increases).

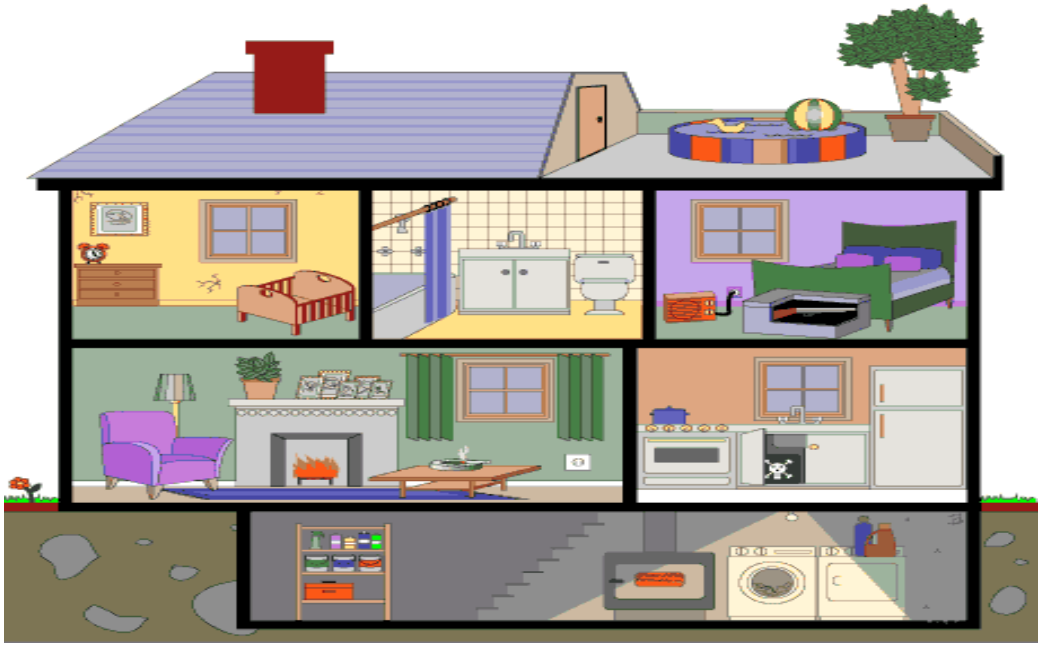
Because radon 222 is an unregulated EPA radioactive contaminant in drinking water, the Portland Water Bureau did not include it in our Water Quality Report in 2013. In past years we

have seen drinking water radon levels from the Columbia South Shore Well field above 350 pCi/L. The Portland Water Bureau continually yet incorrectly states that radon is a non-issue at these levels, yet EPA says "***there is no safe level of radon***". (EPA)

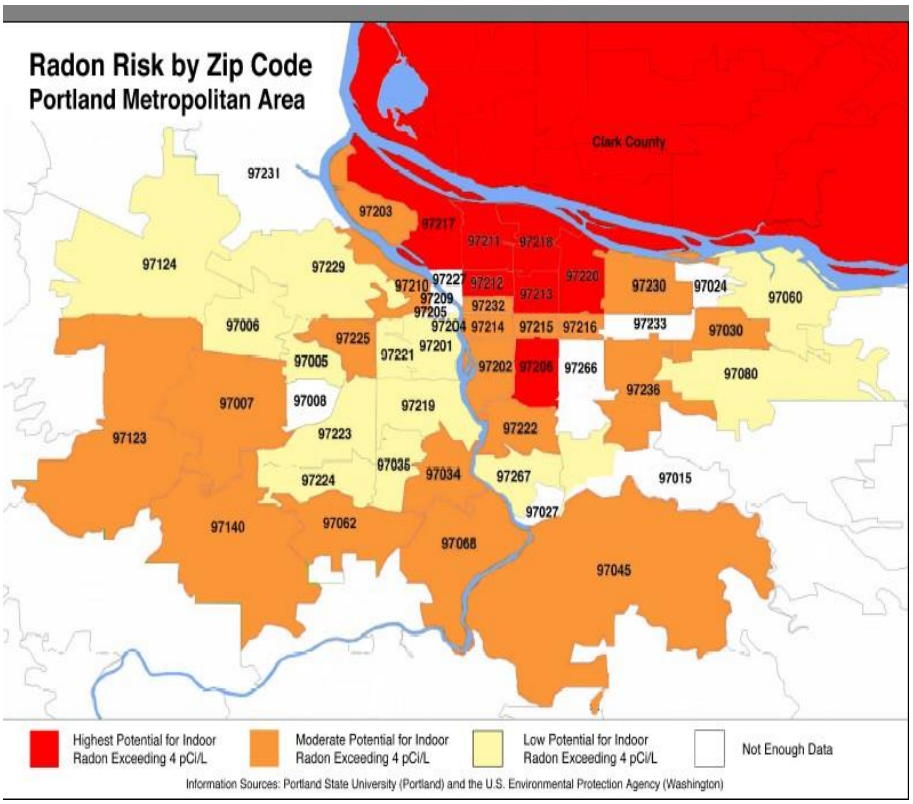
Even at small levels of radon, the cumulative effect of continuous household multiple water uses profoundly impacts the ultimate level of radon and daughter radioactive particles accumulating daily and weekly. Radon needs to be removed from our drinking water even if EPA has not completed a final radon drinking water rule.

National Academy of Sciences (NAS) conclusions are assumptions based on estimates that underestimate the overall public health effect. If the NAS study was acceptable as scientific fact, why was it not adopted by EPA as the standard for the final EPA Radon regulation? EPA says radon is the most cancer causing contaminant, yet there is **no** EPA Radon drinking water regulation.

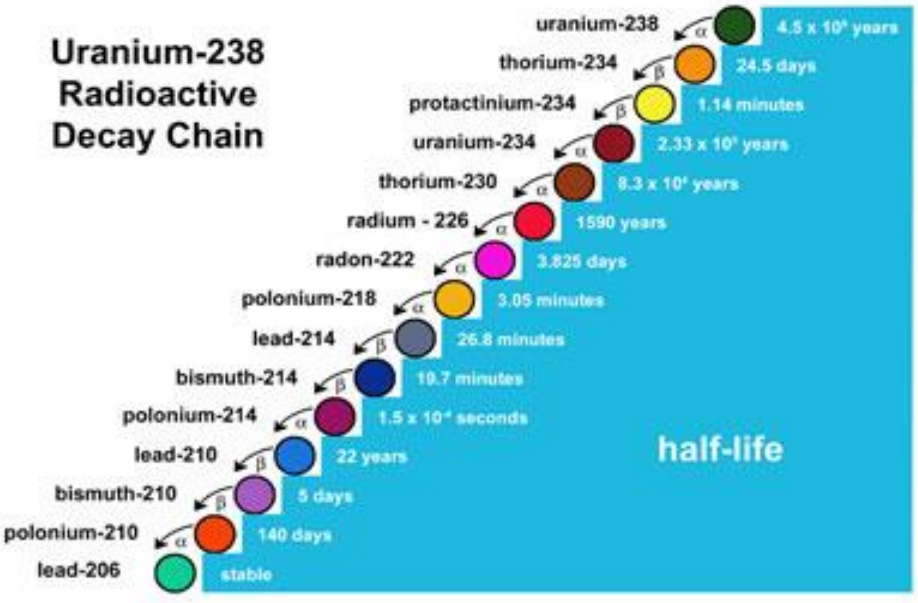
Open reservoirs will harmlessly and efficiently vent the radon and other gases into the atmosphere. Covered reservoirs are not designed for such activity of radon removal. So we begin to see what the effect of even conservatively estimated exposures will present from our closed water system and covered reservoirs.



Radon and other drinking water gases can enter your entire home, school, and workplace through the shower, toilet, washing machine, and faucets. Open reservoirs act as a barrier allowing gases to harmlessly vent into atmosphere before entering distribution system downstream.



Portland metropolitan radioactive radon-222 areas of risk. (US EPA)



Radon -222 is a gas with a half-life of about 4 days. However, the radon 222 decay products are isotopes of *solid elements* and will quickly attach themselves to molecules of water and other atmospheric gases. These, in turn, attach to dust particles. If inhaled, the decay products, whether attached to aerosol particles or 'unattached', will largely be deposited on the surface of the respiratory tract and, because of their short half-lives (↓half an hour), will begin to decay there.

Projection Estimate: Drinking Water Radon-222 Exposure in Closed System During Bull Run Turbidity Event

Radioactive decay process for radon-222 from Portland CSSW drinking water

–Radon-222 decays / 1000 sq. foot house with 4pCi radon = 2,000,000/min (USGS)

–In one hour there would be 120,000,000/hour radon 222 radioactive decays not including progeny.

–PWB CSSW >300 pCi / L radon x .0001 water transfer/air variable = .03 pCi /L (EPA)

1 pCi/L air = 500,000 radon decays/ minute

500,000 x .03 = 15,000 radon decays / minute

Decay time for daughter progeny

–Estimated radioactive decays in ~ one hour with continuous .03 pCi /L exposure

–Radon-222- 60 min. x 15,000 decay/min = 900,000 decay

–Polonium 218- 3minutes

–Lead 214- 29 minutes

–Bismuth 214- ~11 minute

–Polonium 214- <1 second

–Lead 210- 22 years

Estimated Household Impact from Continuous Decay of Radon 222 and Radioactive Decay Chain Progeny Over One-Hour Period

Minutes	RADON 222 α	POLONIUM 218 α	LEAD 214 β Γ	BISMUTH 214 β Γ	POLONIUM 214 α	LEAD 210
1	15kdirect >	15k				
2	15k	15k				
3	15k	15k 3 min >	15k			
4	15k	15k	15k			
5	15k	15k	15k			
6	15k	15k	15k			
7	15k	15k	15k			
8	15k	15k	15k			
9	15k	15k	15k			
10	15k	15k	15k			
11	15k	15k	15k			
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31	15k	15k	15k			
32	15k	15k	15K29min>	15k		
33	15k	15k	15k	15k		
34	15k	15k	15k	15k		
35	15k	15k	15k	15k		
36	15k	15k	15k	15k		
37	15k	15k	15k	15k		
38	15k	15k	15k	15k		
39	15k	15k	15k	15k		
40	15k	15k	15k	15k		
41	15k	15k	15k	15k		
42	15k	15k	15k	15k		
43	15k	15k	15k	15k11min>	15k x 60/min	Stable
44	15k	15k	15k	15k	15k	
45	15k	15k	15k	15k	15k	
46	15k	15k	15k	15k	15k	
47	15k	15k	15k	15k	15k	
48	15k	15k	15k	15k	15k	
49	15k	15k	15k	15k	15k	
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51	15k	15k	15k	15k	15k	
52	15k	15k	15k	15k	15k	
53	15k	15k	15k	15k	15k	
54	15k	15k	15k	15k	15k	
55	15k	15k	15k	15k	15k	
56	15k	15k	15k	15k	15k	
57	15k	15k	15k	15k	15k	
58	15k	15k	15k	15k	15k	
59	15k	15k	15k	15k	15k	
60 min	15k	15k	15k	15k	15k	
	~ 900,000	~ 900,000	~ 855,000	~ 420,000	~ 15,200,000	Decays

Hour = ~18,275,000

Public Health Risks from Showering With Radon-Rich Water

- ~70% of radioactive radon 222 gas is released in shower aerosol into household
- Percentage measurements of radioactive radon 222 gas becoming aerosol from shower heads at different water temperature
- Aerosol dynamics of radon in water before and after shower eventually decaying into radioactive daughter progeny

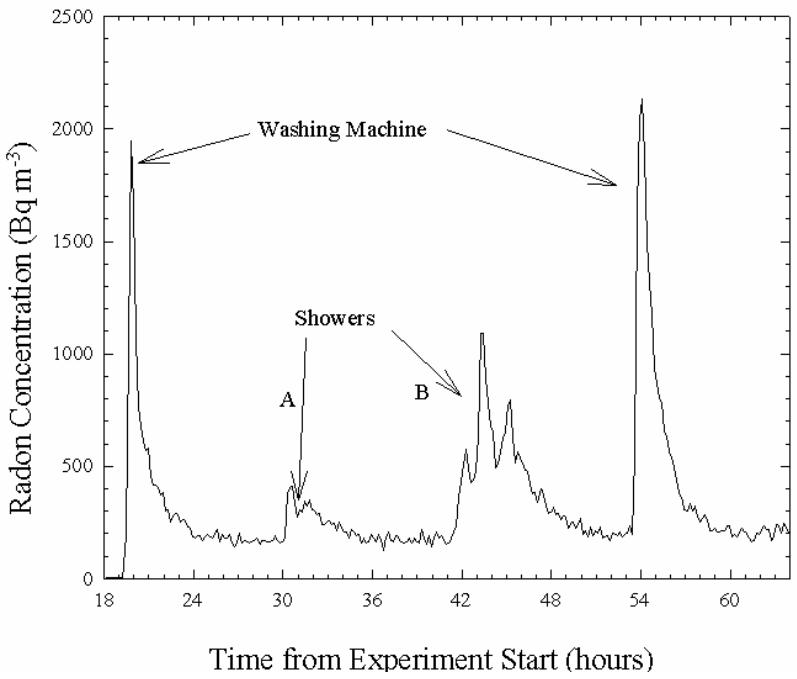
- One of the potentially important sources of short-term exposure is the emanation (discharge) of radon from water during showering and the subsequent in-growth of the radon decay products that continue to produce radioactive materials shower after shower.

TABLE 1. Laboratory Measured Emanation Fraction

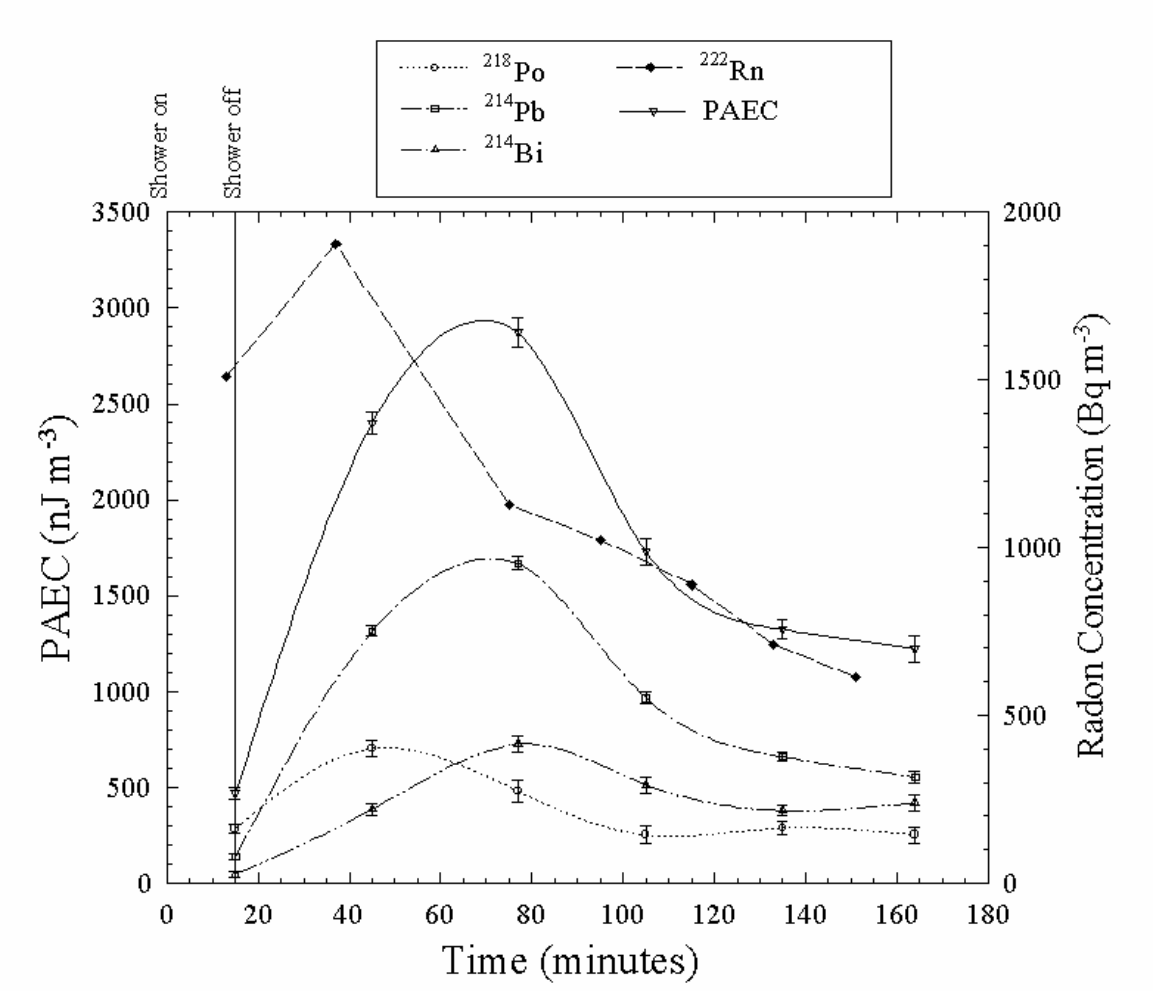
shower head	water temp (°C)	^{222}Rn in water concn before shower (kBq m^{-3})	^{222}Rn in water concn after shower (kBq m^{-3})	emanation (%)
head 1	32	374	108	71
	32	773	233	70
	21	375	124	67
	21	207	58	72
head 2	32	254	69	73

[a] Errors in these values are approximately ±2%.

Household – Aerosol of Radon 222 Gas Exposures from Everyday Activities

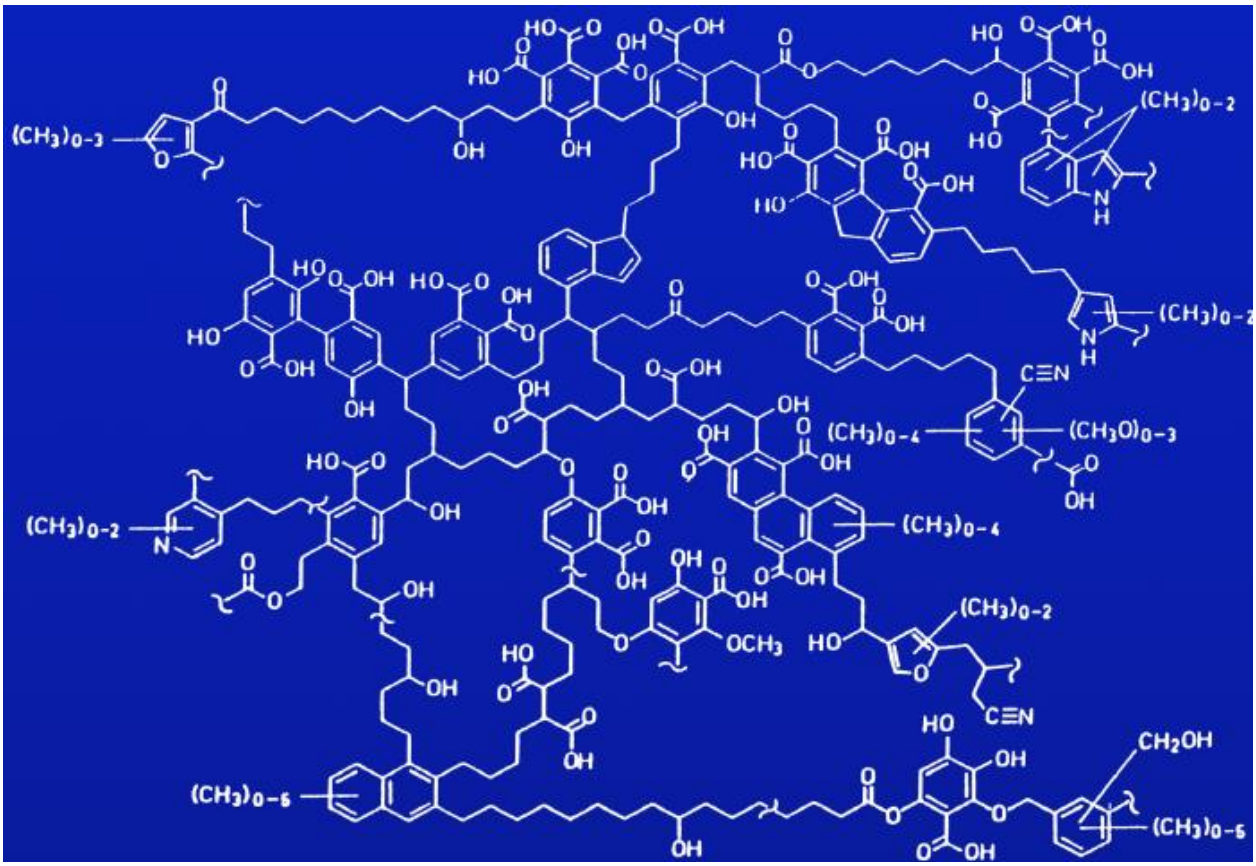


Spikes of radon 222 gas filled drinking water entering home from closed system that did not allow radioactive gas escape, ie., covered reservoirs.



Drinking water- aerosol of radioactive radon decay. Radioactive radon decay appeared later as expected establishing an aerosol presence over a long time period. (PAEC – potential alpha energy concentration) (Ref. 22)

B. Chloroform Formation – Concentration vs. Dissipation



Structure of acidic natural organic material (NOM) reacts with chlorine generating disinfection by-products such as chloroform. Chlorine alone added at Bull Run Headworks in the Bull Run Management Unit watershed for hours of disinfection exposure.

Elimination of Disinfection Byproducts Produced By Chlorine

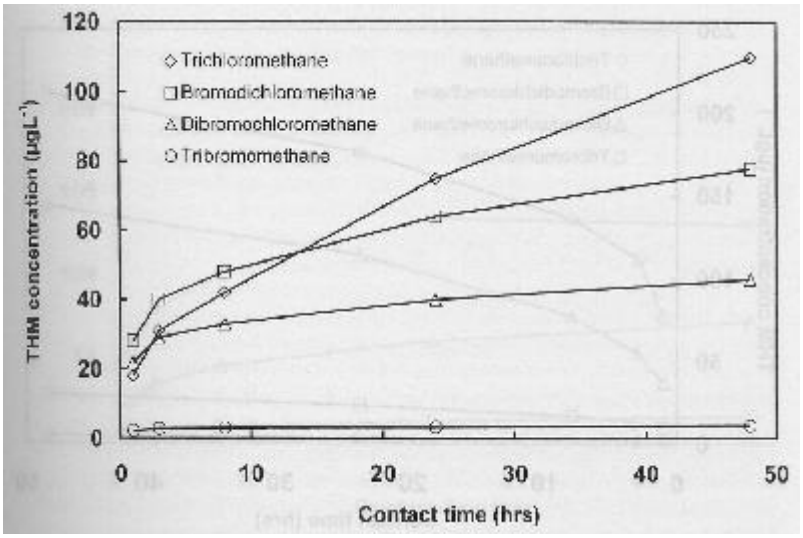
TTHM –Trihalomethanes

Trihalomethanes were among the first disinfection byproducts to be discovered in chlorinated water. These EPA regulated chemical substances are one of many types formed during the disinfection process. The EPA regulated Stage 2 DBP chemicals such as trihalomethanes and haloacetic acids are tested by Portland every three months. TTHM's can be divided into four different classes:

- Trichloromethane (chloroform, $CHCl_3$)
- Bromine dichloromethane (BDCM, $CHBrCl_2$) (no bromines in system)
- Chlorine dibromomethane (CDBM $CHBr_2Cl$)
- Tribromomethane (TBM $CHBr_3$)

These chemicals contain chlorine and bromine but are not in a reaction with methane. These reactions originate with NOM such as humic acid. Chloroform is a commonly occurring trihalomethane and the principle DBP, making it the most important chemical of this group to

remove from our drinking water. One of the important chemical properties of chloroform's environmental fate is its ability to volatilize, easily passing into air as a gas. Open air reservoirs naturally provide volatilization, enhanced through the fountain spray effect as seen in reservoir 6 and water fall/ agitation used in other reservoirs. Open air reservoir actions efficiently vaporize this unwanted toxic gas where it is then harmlessly broken down by sunlight. (Refs. 23-25)



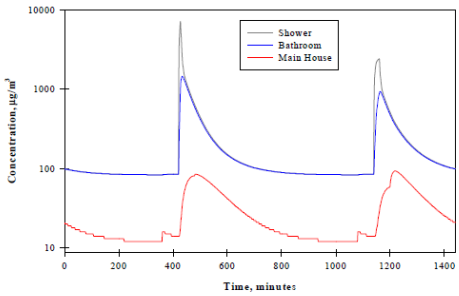
Chloroform (trichloromethane) production v. contact time. Chloroform gas content increases with increase in organic material contact time. PWB distribution system has been poorly maintained leading to increase in biofilm/sediment reactions resulting in greater chloroform gas generation. Open air reservoirs allow increases in chloroform to vaporize before entering distribution.

Covered reservoirs distribute toxic and carcinogenic contaminants into homes daily

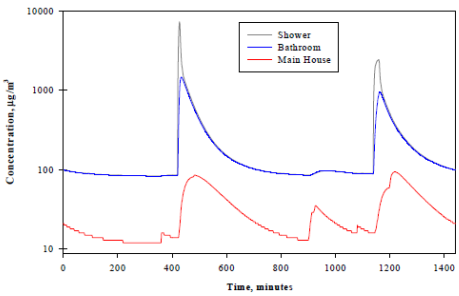
Reasons for open reservoirs and unwanted chemicals

"***Some people who drink water containing haloacetic acids in excess of the MCL over many years may have an increased risk of getting cancer. Some people who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer."*** (EPA)

The following diagrams demonstrate how chloroform can increase – in a home supplied with water from a covered reservoir system – through drinking water aerosols formed through evaporation or routine activities such as showering, bathing, washing clothes, and cleaning. Because of the high Henry's Law constant, inhalation can provide the greatest public health risk by absorption in the human respiratory system including the surface of the lung. The primary factor that determines the relative magnitude of deposition in different regions of the respiratory tract (nose, airways, and alveolar) is the particle size distribution of the aerosol. Another potential source of exposure from aerosols is via dermal sorption when the aerosols are deposited on the exposed skin surface during different water use activities. Open reservoirs can reduce or eliminate THM chloroform gases using efficient open air reservoir volatilization before entering homes, schools, and work places.



a: Concentration Profile of Chloroform – Washing Machine Off



b: Concentration Profile of Chloroform – Washing Machine On

(a.) Concentration of household drinking water chloroform: shower, bath room, main house. Washing Machine OFF
(b.) Concentration of drinking water chloroform increasing: shower (top), bathroom (middle), main house with washing machine ON (bottom) (Ref. 26)

Waterfall effects of an open reservoir promote volatilization of gases before they enter your home.

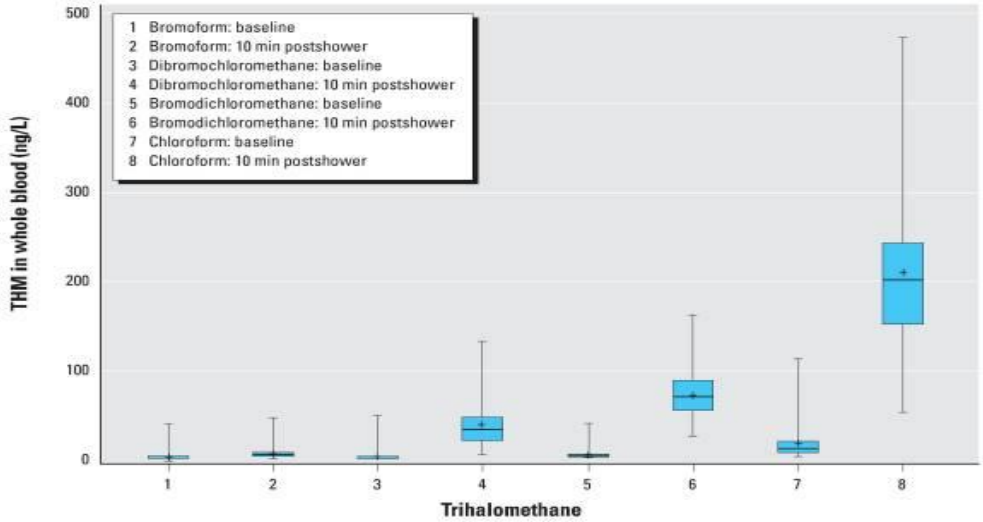
Water use in homes contributes considerably to levels of chloroform in indoor air and total exposure. Toxic and carcinogenic chloroform can enter your body in four ways: as you breathe, eat food, drink water, and it easily passes through your skin as you take a bath or shower. Chloroform can cross the placenta and is also found in breast milk. When chloroform crosses the placenta in humans, it can result in concentrations in fetal blood that are greater than maternal blood concentrations.

An epidemiological study indicated an association between chloroform concentrations in drinking water and intrauterine growth retardation. Concentrations of chloroform in indoor air were higher than those in ambient outdoor air owing primarily to volatilization during water use. When the shower water is hot enough for it to vaporize, inhalation of even more chloroform will occur. Ongoing and continuous exposures to chloroform – such as showering from the inefficiently vented closed reservoir water system – can allow for increased toxicity. Studies in people and in animals show that after you breathe air or consume food that contains chloroform it can quickly enter your bloodstream from your lungs or intestines.

Chloroform is carried by the blood to all parts of your body, such as the nervous system, fat, liver, and kidneys. Indoor air exposure to the volatile THMs such as chloroform is particularly important with houses having low rates of ventilation and high rates of showering and bathing. Chloroform is a California Proposition 65 carcinogen. (Refs. 27-30)

Open Reservoir Atmospheric Volatilization – Total Trihalomethanes (TTHM)
THM concentrations were important predictors of blood THM concentrations immediately after showering. Chloroform concentrations in the shower stall air are the most important predictor in determining blood concentrations after the shower.

Chloroform can be degraded photo-chemically by sunlight and evaporates easily utilizing the open reservoir air surface/ water partial pressure differences in promoting atmospheric volatilization. The open reservoirs provide significant opportunities to efficiently volatilize toxic and carcinogenic THMs. In a closed system such as a covered reservoir, such sunlight degradation and atmospheric volatilization does not occur.



High chloroform blood level saturation from shower shown at 7 & 8. (Ref. 31)

More EPA Regulated Disinfection By-Products Generated from Chlorine and Chloramine

Haloacetic Acids – HAA_5
The five most common are

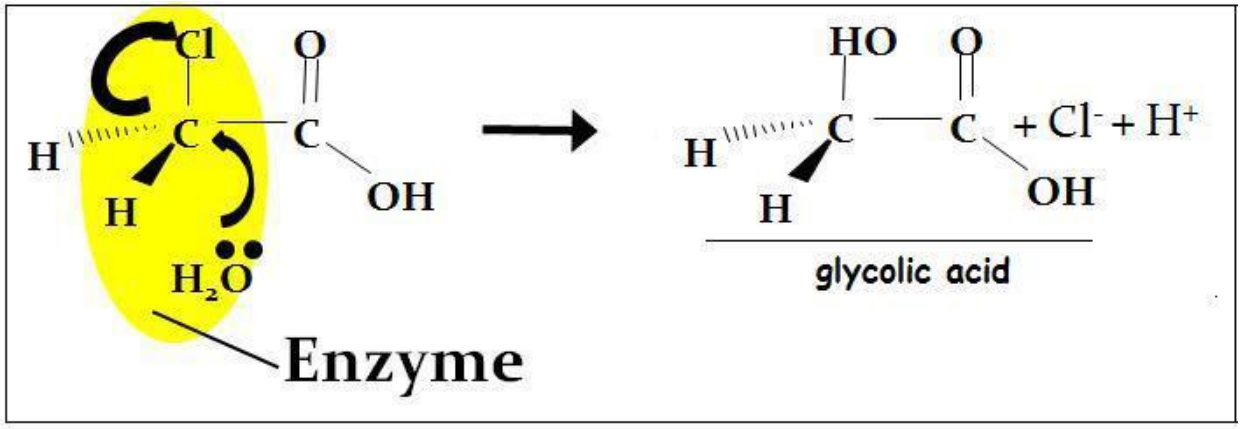
- Monochloroacetic acid (MCAA) ClCH2COOH
- Dichloroacetic acid (DCAA) Cl2CHCOOH
- Trichloroacetic acid (TCAA) Cl3CCOOH
- Monobromoacetic acid (MBAA) BrCH2COOH
- Dibromoacetic acid (DBAA) Br2CHCOOH

In addition to trihalomethanes (THM), haloacetic acids HAA_5 are a class of disinfection byproducts produced by chlorine and chloramine chemical reactions with natural organic material in the water. These disinfection byproducts are also regulated by EPA because of public health concerns. Loss of HAA_5's in water distribution systems has been frequently attributed to biodegradation. Experimental *aerobic* biodegradation rates have shown to be rapid. Oxygen loving aerobic bacteria are associated with the biodegradation and removal of the HAA_5's toxic and carcinogenic disinfection byproducts. Aerobic bacteria have a beneficial role in suppressing the concentrations in tap water. They are integral part of the efficient HAA_5 removal in drinking water such as open reservoir system. (Refs. 32-35)

Oxygen loving aerobic bacteria in our open reservoirs can biodegrade and remove HAA_5 from water

HAA_5 are the second most prominent class of EPA regulated drinking water halogenated disinfection byproducts and are water soluble. HAA_5 chemicals such as DCAA and TCAA present a toxic and potentially hepatocarcinogenic public health hazard that can be expected to be detected in chlorinated drinking water distribution systems. Genotoxicity, reproductive toxicity, embryo toxicity, neurotoxicity and immunotoxicity of DCAA have also been reported. The presence of DCAA and TCAA increases the toxicity of chloroform in female animal studies. (Refs. 36-38)

Microbial removal of these HAA_5's increases water quality and health.



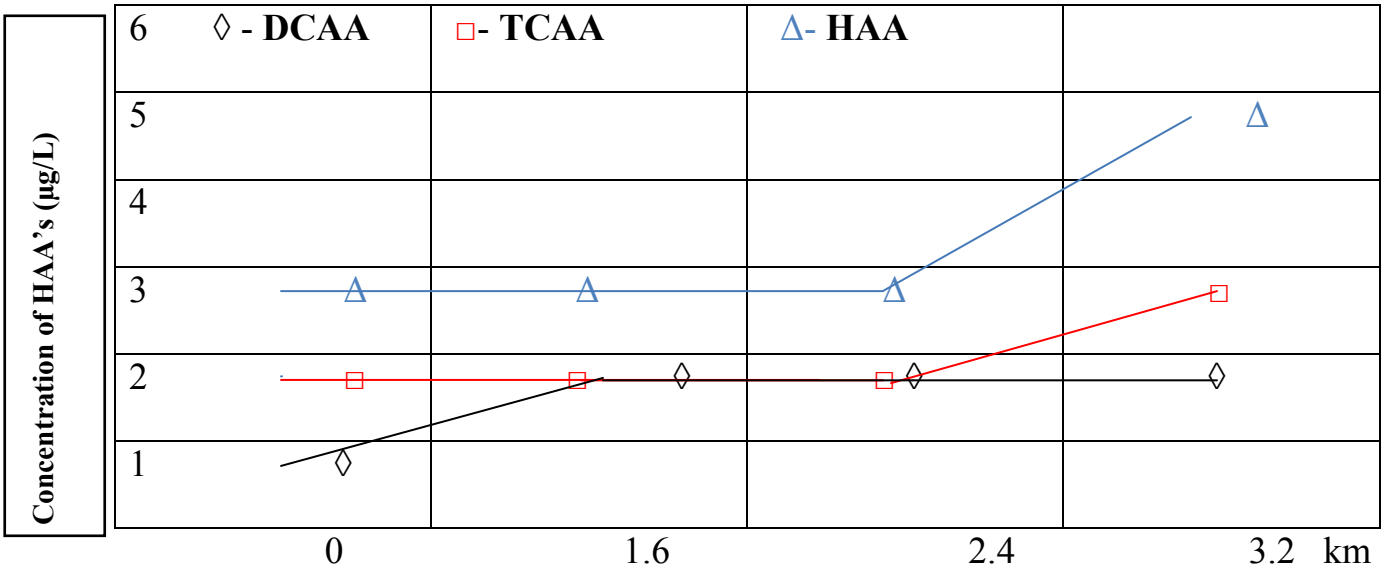
Potential bacterial biodegradation pathway of MCAA. Glycolic acid is then in the general metabolism, and may be photodegraded by sunlight, stopping the HAA from being able to biopersist or bioaccumulate in the environment. (Refs. 39-40)

Summary of how open reservoirs provide support removing HAA_5

- The open reservoirs can provide a natural and sustainable aerobic biodegradation process of the unwanted HAA_5
- Different bacteria are known to aerobically degrade HAA_5 either co-metabolically or as a sole carbon and energy source
- Because HAA_5 are biodegradable compounds they can utilize the enhanced efficiency of *aerobic* microorganisms as a benefit for the open reservoir drinking water quality

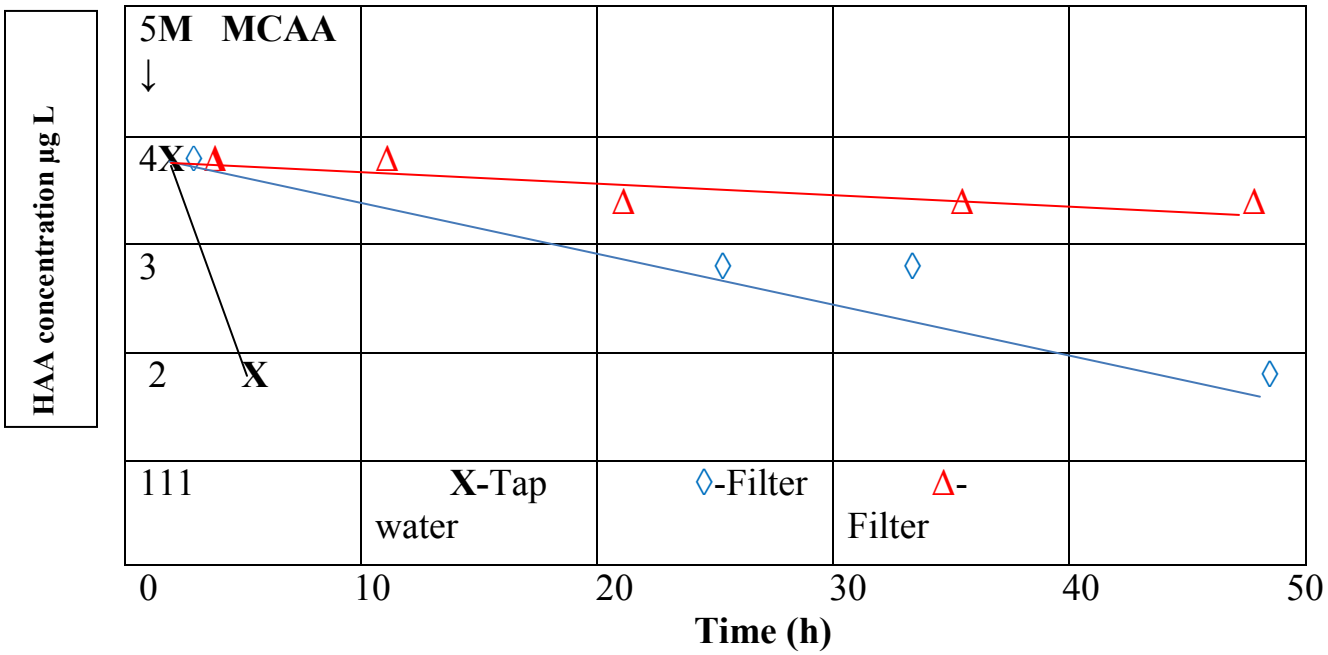
- Aerobic microorganisms are 18 times more efficient in metabolizing chemical compounds than the *anaerobic* microorganisms, found in closed and covered reservoirs
- Oxygen loving aerobic microorganisms degrading HAA_5 act as another desirable public health barrier found in the open reservoirs
- Photolysis/ sunlight can provide additional degradation pathways for HAA_5 in natural waters
- Open reservoirs support peroxide formation in aerobic biodegradation as a mechanism for reduction HAA5 in surface waters before entering distribution systems
- **Aerobic biodegradation in open reservoirs provides superior public health benefits to the anaerobic conditions of covered and closed reservoirs**

Haloacetic Acids Increase in Poorly Maintained Distribution System

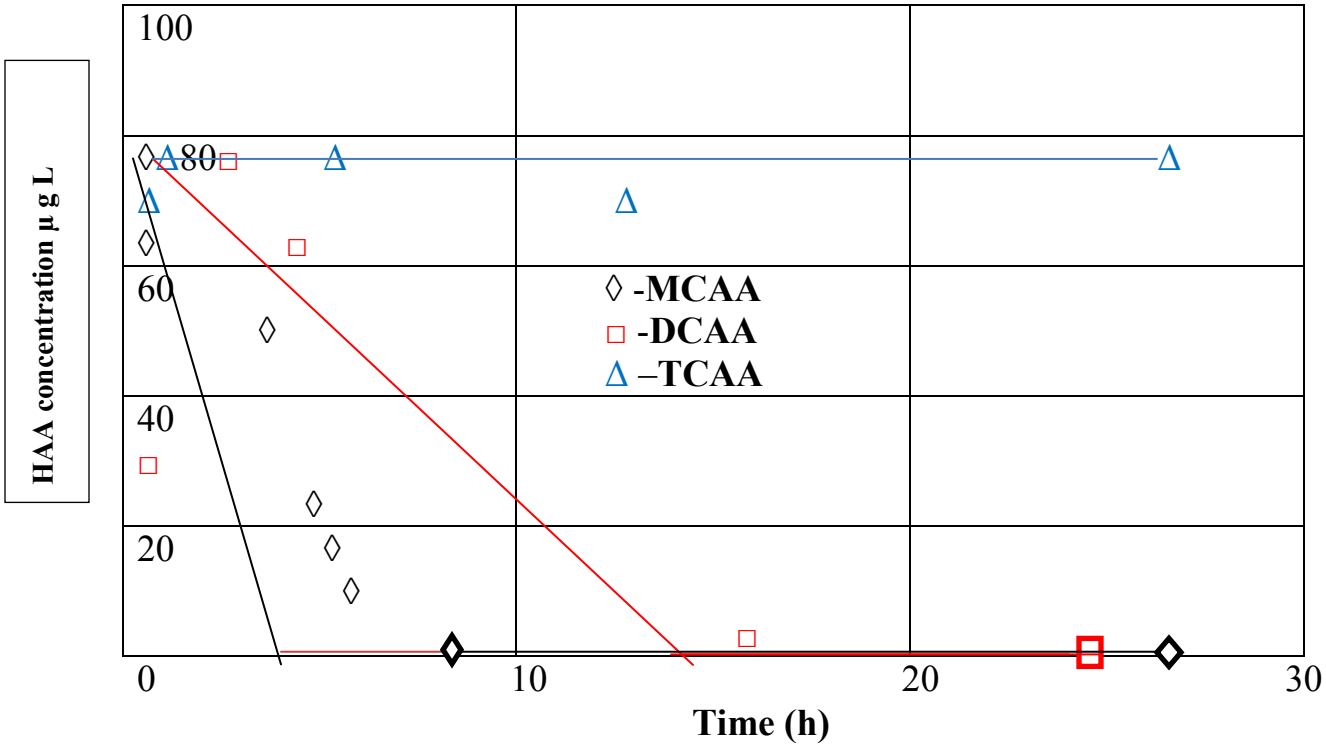


Biofilm from poorly maintained distribution system, i.e., Portland Water Bureau, can increase HAA from continuous chlorine reaction in water pipes

Aerobic Microbial Degradation of Haloacetic Acids - HAA's



HAA Biodegradation by Selected Isolates-R2A DR8 Pseudomonas Tap Water



HAA Biodegradation - R2A-DR11 Aquabacrterium sp. Tap Water

Isolation of HAA degrading bacteria from drinking water using complex media (Ref. 41)

C. Other Disinfection Chemicals – Higher vs. Lower Use

EPA Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage2DBP)
The Bull Run drinking water system was designed by highly accomplished engineers who incorporated the brilliant scientific and public health principles established within fundamental laws of chemistry and physics. As a continued reminder our Bull Run drinking water system was designed with **three critical public health barriers**:

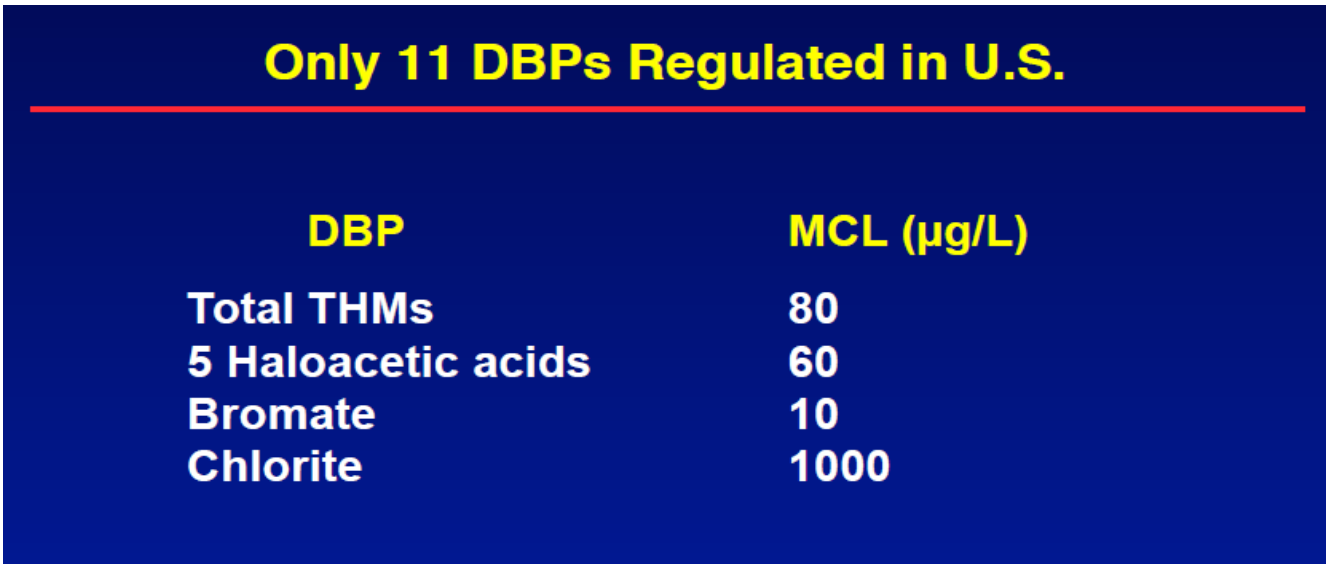
- Portland is truly fortunate to have the federally protected closed to human entry Bull Run Management Unit as our first public health ***barrier***, providing safe drinking water free of municipal, industrial, and agricultural sewage exposure that are the primary sources of US surface drinking water contamination.

- The second ***barrier*** is simple chlorine/ammonia as a disinfection process that provides protection against waterborne disease causing microorganisms.

- Portland's open reservoirs provide a crucial third ***barrier*** by removing unwanted gases, chemicals, and disinfection byproducts (DBP) using natural sustainable aerobic processes before entering our major distribution system. Open reservoir removal of toxic and carcinogenic chemical DBP take place through the following processes:
  -Volatilization efficiency -Biodegradation-microbial
  -Aerobic activity/oxygenation -Photolysis/sunlight -Water agitation

We Need Open Reservoirs to Address the Environmental Chemical Challenges of the Future

The **EPA Stage 2 Disinfectant Byproduct Rule** is intended to reduce potential cancer, reproductive, and developmental health risks from disinfection byproducts which form when disinfectants are used to control microbial pathogens. Our open reservoirs not only currently meet EPA LT2 needs but are also needed to enhance the removal of the EPA regulated trihalomethanes (TTHM), haloacetic acids (HAA_5), as well as other toxic chemicals before these can enter our homes, schools, and workplaces. Natural aerobic atmospheric volatilization of gases and biodegradation of DBP chemicals from open reservoirs diminish the related potential health risks and can provide more efficient public health protection than covered reservoirs can offer. Long-term EPA drinking water standards do not include children but are based on 70 kg /+154 lb. ***adults***. Further DBP chemical removal enhanced by our open reservoirs is needed to decrease public health risk for children, pets, as well as adults.



Toxic and carcinogenic disinfection byproducts regulated by EPA Stage 2DBP

List of EPA's 11 regulated DBP's – sampled only 4 times / year

Total Tri Halo Methanes (TTHM's)

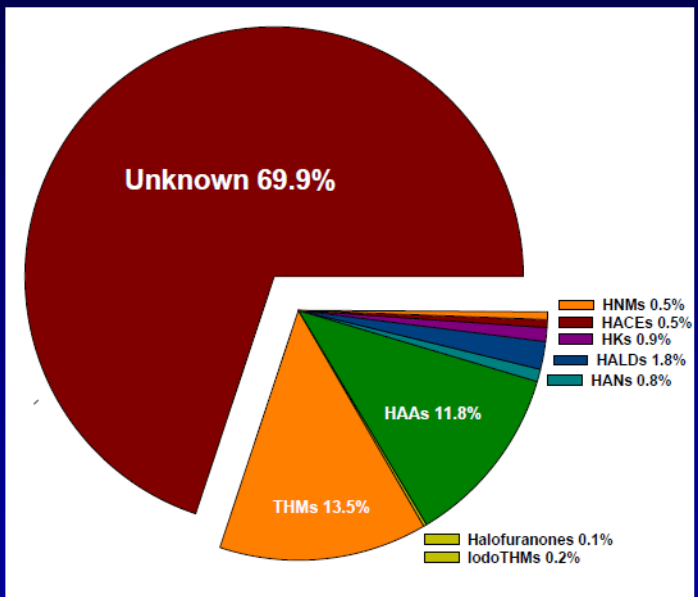
- Chloroform – most prevalent
- Bromoform
- Bromodichloromethane
- Dibromochloromethane

Halacetic acids (HAA's)

- Monochloro
- Dichloro
- Trichloro
- Monobromo
- Dibromo
- Bromine-
- Chlorite-

In addition, many disinfectant byproducts are not known or well-studied. Open reservoirs can reduce/remove many toxic and carcinogenic chemicals before being inhaled, ingested, and absorbed through skin exposures.

But, more than 50% still not known….



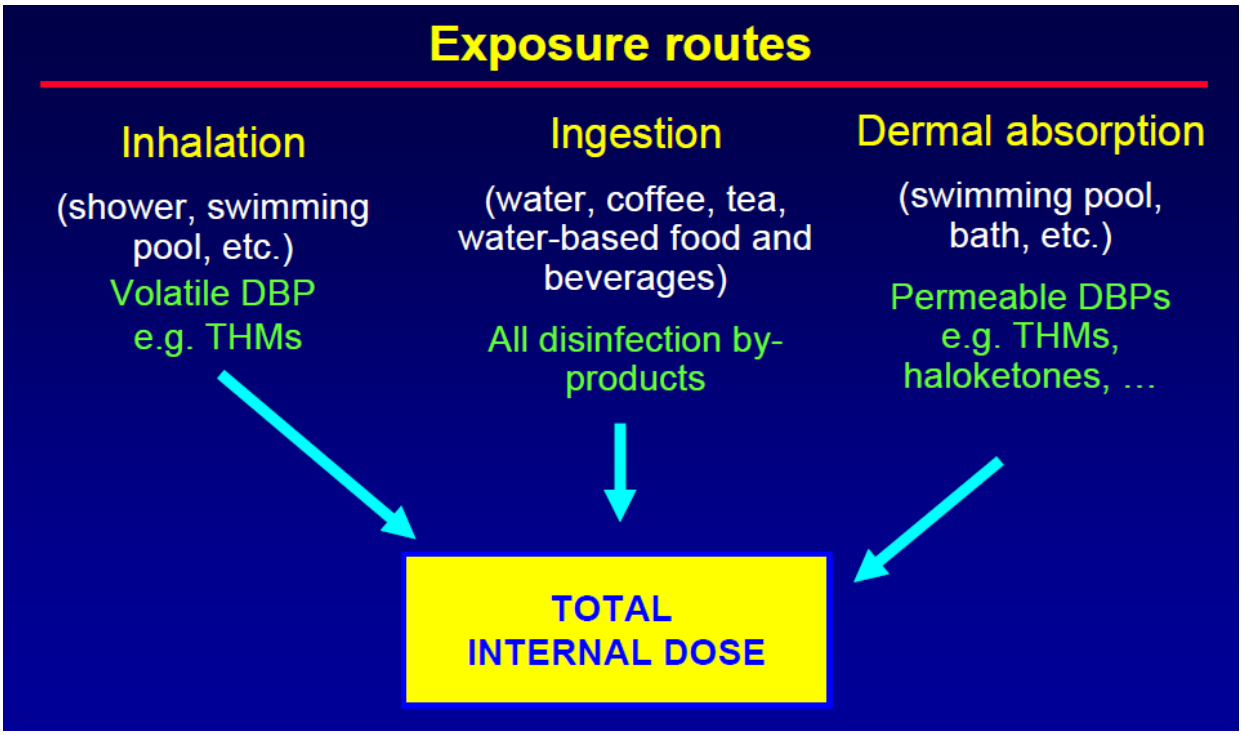
(US EPA)

>600 DBPs Identified

Halogenated DBPs
- Halomethanes
- Haloacids
- Haloaldehydes
- Haloketones
- Halonitriles
- Haloamides
- Halonitromethanes
- Halofuranones (e.g., MX)
- Oxyhalides (e.g., bromate)
- Many others

Non-halogenated DBPs
- Nitrosamines
- Aldehydes
- Ketones
- Carboxylic acids
- Others

(US EPA)

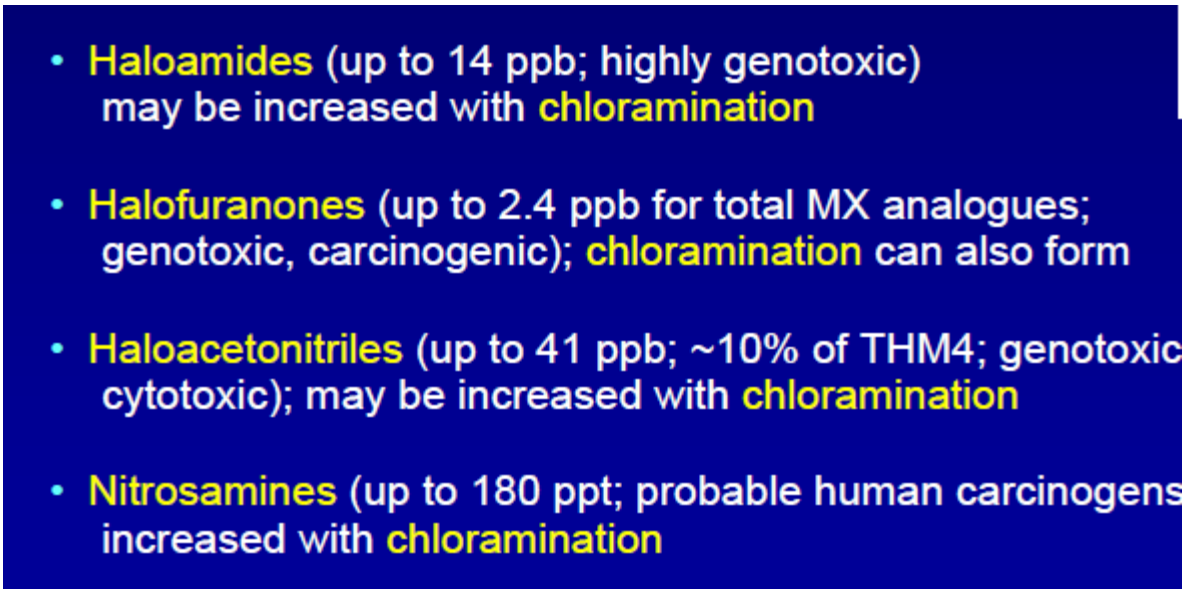


(US EPA)

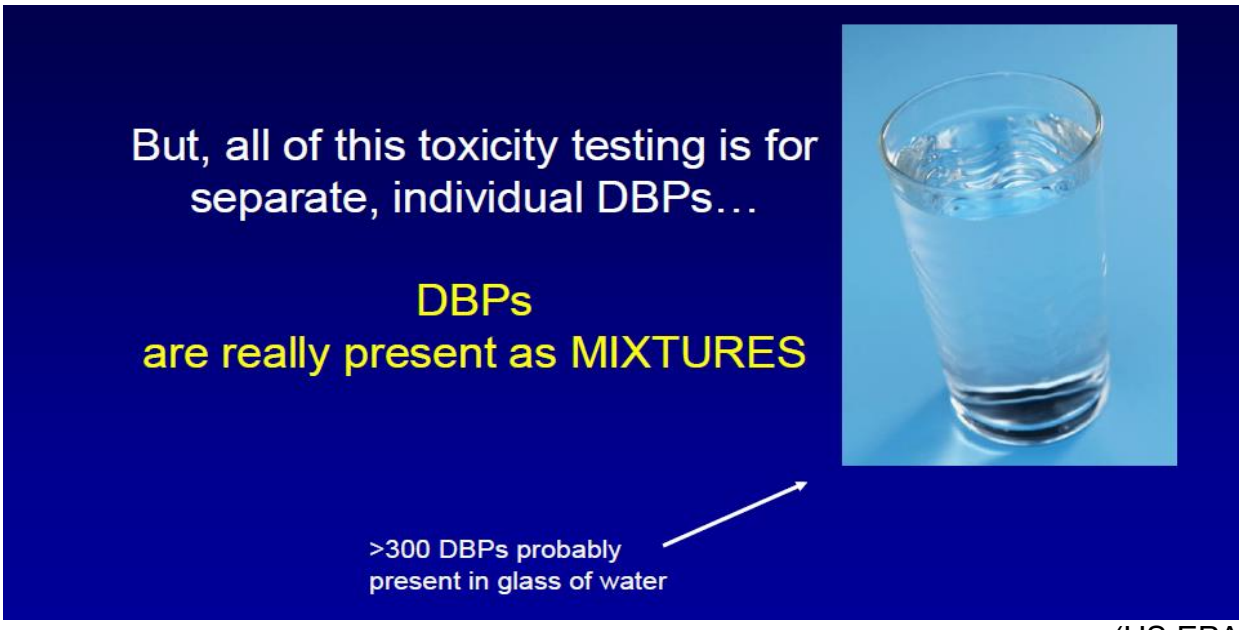
Route of exposure is important….

- Can get 2X exposure from 10 min shower compared to drinking 2L of tap water (inhalation)
- Some DBPs dermally absorbed
- Evidence of increased bladder cancer with swimming in indoor pools (inhalation, dermal): Villanueva et al., *Am. J. Epidemiol*. 2007, *165*, 148-156.

(US EPA)



Emerging Chloramination Disinfection By-Products (US EPA)



(US EPA)

D. Nitrification – Presence vs. Absence

Nitrification is a microbial process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized (broken down) to nitrite and nitrate. Ammonia can be present in drinking water through either naturally-occurring processes or through the addition of ammonia to the already present chlorine, during the secondary disinfection process to form chloramines. Drinking water chloramines provide the greatest source of nitrogen which under certain conditions can be used to produce the nitrites/nitrates eventually leading to nitrosamines.

Ultraviolet light depletes free chlorine, whereas chloramines seem to be quite stable in sunlight. Although monochloramine can degrade *slowly* when exposed to the atmosphere at varying rates depending on the amount of sunlight, wind, and temperature, the nitrifiers (bacteria) are very sensitive to near UV, visual, and fluorescent light. Consequently, nitrification episodes in distribution systems occur in the dark (in covered reservoirs, pipelines, taps, etc.) Because of exposure to sunlight, nitrification has not been generated in open reservoirs. (Refs. 42-44)

The nitrification process is primarily accomplished by two groups of autotrophic (self feeding) nitrifying bacteria.

Step 1- Nitrosomonas sp. oxidizing ammonia → nitrite

$$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$$

Step 2- Nitrobacter sp. oxidizing nitrite → nitrate

$$NO_2 + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$$

The two groups of bacteria commonly found in aquatic environments can break down ammonia into nitrite and nitrate. The presence of nitrite in a water supply is undesirable because of health concerns such as methemoglobinemia where nitrogen replaces oxygen in red blood cells. Nitrite can also accelerate the decomposition of monchloramine and interfere with chlorine and chlorine residual measurements.

Increased chlorine demand and decay change the disinfectant residual (concentration levels) as it travels through the distribution system as monochloramine. Ammonia concentrations naturally increase as the chlorine concentration decreases through this process***. Sunlight in open reservoirs inhibits nitrification bacteria from oxidizing ammonia to nitrite and nitrate***. Application of chlorine at the reservoir outlet binds to the ammonia efficiently and cost-effectively increasing chloramine residual downstream in the distribution system. ***The absence of sunlight and the dark environment in closed and covered reservoirs allows microbial nitrification activity to continue oxidizing ammonia into unwanted nitrite and nitrate, etc***. Nitrification issues have been documented in Los Angeles covered reservoirs such as Garvey and Orange County.

N-nitrosodimethylamine (NDMA) important nitrogenous chemical reaction-

Nitrate → nitrite → nitrosamines

Chlorine and chloramine can react with organic nitrogen material that can contain precursors to NDMA. NDMA is routinely detected in drinking water utilities. NDMA detection may vary during seasonal changes due to differences in organic material levels. Water quality data from surface water sampling demonstrated that NDMA is significantly broken down in surface water due to ultraviolet degradation from exposure to sunlight. Based on the data, a half-life of 2.2 hours in surface water was estimated for NDMA.

Photo degradation (sunlight) is the main process for removing NDMA from the aquatic environment, yet NDMA can persist in the absence of sunlight such as in a closed and covered reservoir. From a covered reservoir the toxic NDMA continues on into the drinking water distribution system to be consumed in our homes, schools and businesses. (Refs. 45-46)

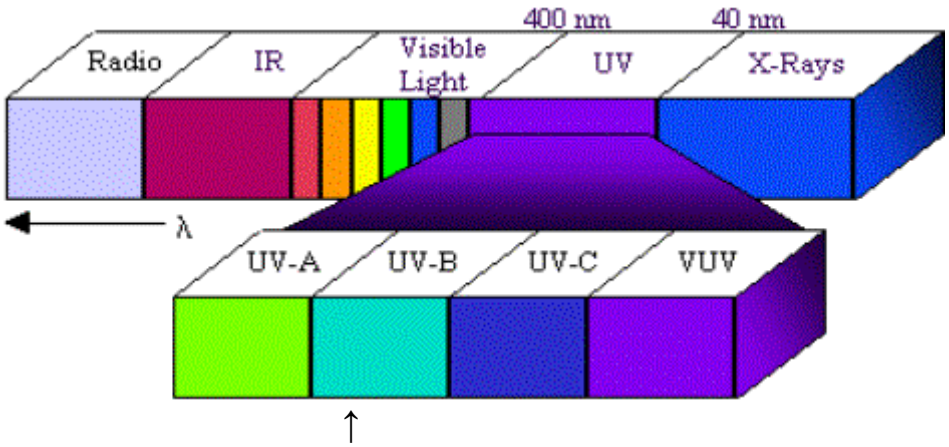
N-Nitrosodimethylamine (NDMA) is a member of a family of extremely potent carcinogens, the *N* – nitrosamines. Their cancer potencies are much higher than those of THM's. Concerns about NDMA mainly focused on the presence of NDMA in foods and drinking water. NDMA has produced liver tumors and parenchymal cell tumors when administered orally**. NDMA acts as a transplacental carcinogen and has been found in breast milk**. NDMA can be inhaled, and absorbed through the skin. Increases in lung, liver, and kidney tumors have been observed after inhalation exposure. NDMA is structurally related to known carcinogens and can be mutagenic in microorganisms. (Refs. 47-50)

"Blue Baby"syndrome from nitrification of drinking water. Nitrate poisoning where red blood cells have decreased oxygen, resulting in *methemoglobinemia*

E. Oxygenation – Absence vs. Presence

Oxygen introduced at the open reservoirs' fountains and waterfall inlets saturates the water and provides many public health benefits. Oxygenation provides a secure environment for helpful aerobic bacteria, reduces unwanted anaerobic bacteria, and provides a natural source for disinfection precursors such as oxides and peroxides. Oxygen enriched water naturally enhances aerobic bacteria metabolism, yielding a superior efficiency in chemical biodegradation than anaerobic bacteria metabolism found in covered reservoirs. Closed and covered reservoirs do not provide these advantages.

F. Light Disinfection – Broad Spectrum Sunlight



Natural broad spectrum sunlight benefits in open reservoirs. The many wavelengths of natural sun light provide well established disinfection properties that artificial UV used in drinking water treatment cannot. Arrow at UV-B shows the artificial UV radiation 254 nm wavelength used for drinking water facilities. The single wavelength 254 nm provides significantly less energy to break down microorganisms than does natural sunlight.

Natural disinfection from sunlight is well known. Sunlight is among the most potent abiotic factors in the inactivation or killing of bacteria and other microorganisms in water. Sunlight imparts a broad and effective spectrum of photon wavelength exposures that include: gamma, x-ray, ultraviolet, visual, infrared. Sunlight photolytically (breaks apart) reacts with and disrupts microorganism chemical structures. Additionally our open reservoirs incorporate efficient oxygenation of water at the fountains and the inlet waterfalls, synergistically enhancing microbial disinfection. This is achieved when sunlight photons react with oxygen-based molecules forming free radicals and oxides such as peroxide. These chemicals also react with microbial structures providing a sustainable and natural disinfection effect. Covered and closed reservoirs cannot provide the natural disinfection benefits of sunlight.

The condition of oocysts is very important in determining the risk of infection. Oocysts are exposed to many conditions in the environment that can reduce their infectivity before entering the distribution system. The length of time post shedding, water temperature, and the amount of

ultraviolet UV exposure from sunlight can effectively reduce oocyst infectivity. Although oocysts are considered environmentally resistant they exhibit considerable loss of infectivity as environmental temperature increases. Above 50^0F loss of infectivity increases. In addition, surface waters are exposed to natural UV irradiation in sunlight which may damage oocyst DNA therefore inhibiting DNA replication and reducing infectivity. Due to specific gravity influences, many organisms such as Cryptosporoidium, Giardia, etc., exist at the top of the water column surface where UV sunlight can easily render them harmless. (Refs. 51-53)

G. Public Health Record of Closed Reservoirs

From 1949-1969 the American Water Works Association, American Public Health Association, and U.S. Public Health Service proposed covering reservoirs ***even though there were no historical or current public health problems with open reservoirs.*** While these organizations were covering reservoirs for alleged public health reasons, closed reservoirs were being built and maintained with materials such as ***lead-based paints and petroleum-based coatings*** on the interior of these reservoirs. As early as 1904 lead-based paints were recognized as toxic. Since the 1920's *benzene*, a component of petroleum-based coatings, has been known to cause cancer. Thus, these materials have been widely known and recognized for decades as toxic and carcinogenic while in direct contact with drinking water. These toxic and carcinogenic chemicals can still be found and used with closed reservoir structures placing drinking water and public health at risk. (Ref. 54)

Although the covered reservoir storage facility is normally an enclosed structure, numerous access points can become entry points for debris and contaminants. Consumer deaths from closed reservoirs are historically well-documented from these points of entry.

These contaminant pathways include roof top access hatches, sidewall joints, vent and overflow piping, roof cracks, and workmanship inconsistencies.

The most common problems reported from inspectors in covered reservoirs:

- No bug screens on vents and overflows
- Cathodic systems not adjusted or operating properly
- Unlocked access hatches
- Presence of lead paint (interior and exterior) and the presence of unapproved paints

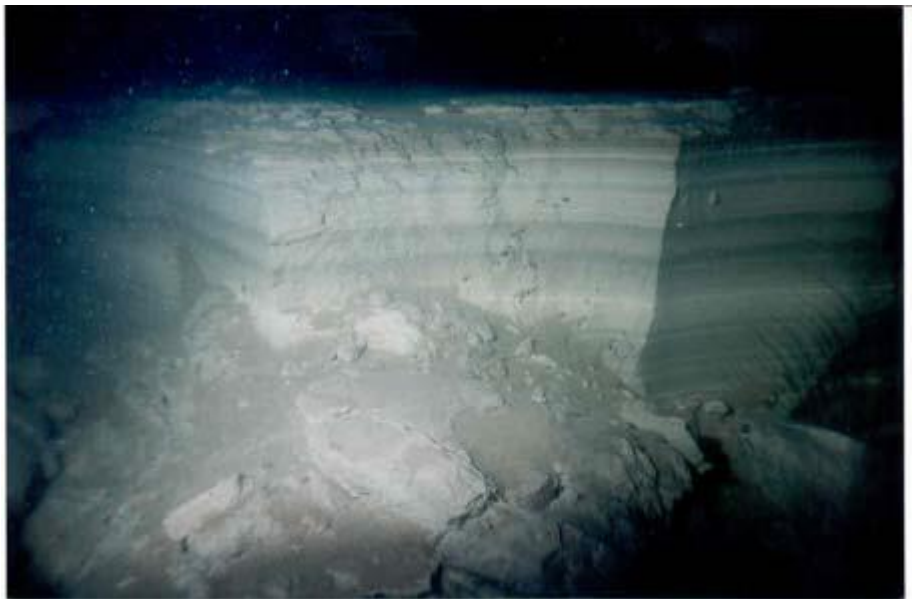
Common coating problems reported by tank inspectors relating to water quality:

- Chemical leaching from incompletely cured coating
- Corrosion product buildup from excessive interior corrosion
- Turbidity events from bottom sediments
- Unknown chemical leaching from non-approved coatings and lead leaching from lead-based interior coatings

Points of public health concern:

- Disinfectant decay – nitrification facilitation from dark environment
- Chemical contaminants – toxic and carcinogenic coatings

- DBP retention – lack of atmospheric volatility
- DBP retention – lack of sunlight
- Tastes and odors – anaerobic flora metabolites
- Sedimentation / biofilm – less-frequent cleaning schedule +5 years
- Microbial contaminants – known source of many consumer deaths
- Roof leakage and contamination cement seams (Seattle)
- Roof leakage and benzene from rubberized asphalt degrading (Seattle)
- Accumulation of toxic filtration media remaining in seldom-cleaned tanks



Unhealthy accumulation of post-filter media in drinking water: aluminum sulfate (alum) in seldom-cleaned covered reservoir. (Ref. 58)

Microbial case studies

Covered reservoir storage facilities have been identified in microbial drinking waterborne disease deaths and outbreaks:

- In 1993 Salmonella typhimurium was identified in a Gideon, Missouri, outbreak from bird contamination in a covered municipal water storage tank. Pigeon droppings from the roof area carried into the openings of a closed tank were identified as the etiological agent. Seven persons died, and hundreds became ill.

- Also in 1993, a Campylobacter jejuni outbreak in Minnesota from a drinking water storage tower. Fecal coliform were also found.

- In 2008, Salmonella typhimurium caused another death and hundreds of illnesses from a covered drinking water reservoir in Alamosa, Colorado. Contaminants identified from bird access unobserved in covered reservoir.

Covered Alamosa, Colorado reservoir where Salmonella bacteria from prolonged bird roosting exposures were not visible or detected, causing illness and death

Concerns from Questionable Water Engineering Judgment Decisions: Past and Current Covered Reservoir Surfaces Coated with Toxic Materials

Coating materials are used to prevent hydrostatic (water) moisture migration in concrete tanks, pH changes, and corrosion of steel storage tanks. Coatings used in finished water storage facilities were selected because of their structure protection and ease of application. The common use of coal tars, greases, waxes, and lead paints as interior tank coatings was accepted by engineers. These products contributed significant toxic chemical exposure to the drinking water. Grease coatings can differ in their composition from vegetable to petroleum and can provide food for bacteria resulting in disinfection problems along with taste and odor issues in finished water.

Toxic chemical case studies:

- Petroleum grease applied in 1925 in a Florida storage tank interior caused odor, taste, disinfectant, and slime problems. In 1988 the grease was reapplied. The grease was removed in 1996 and a polyamide epoxy was applied.

- East Bay Municipal Utility District used hot-mopped coal tar as their interior coating material for tanks through the 1960's. Hot-mopped coal tar is still seen today in operating water tanks at other utilities.

- Structural and building designs continue to be problematic in closed and covered reservoirs. Cracks in the ceiling of the new 2009 Seattle reservoirs can allow for intrusions of contaminated water and be problematic, regardless of the rubberized asphalt

barrier replacement. The new toxic and carcinogenic material placed over cracks in the reservoir ceiling is a petroleum based asphalt/benzene material. Microorganisms can break down the petroleum-based carbon substrate releasing benzene and other toxins into reservoir ceiling cracks and water.

There are newer coating applications such as aluminum, polyurethane, and chlorinated rubber. Leaching of organic contaminants from flat steel panels can occur with various coatings including vinyl, chlorinated rubber, epoxy, asphalt, and coal tar, etc. Coal tar coating and lining can still be found, and is used in California as a coating material. Elevated levels of alkyl benzenes and polycyclic aromatic hydrocarbons (PAH's) have been reported in coal tar bituminous coatings. In tanks that remain in use, organics can be leached into drinking water, especially if there is not enough curing time after coating application.

Additional closed reservoir chemical problems occur from reduced disinfectant residual and sedimentation. Debris can enter any closed reservoir system. Cleaning schedules in closed reservoirs are recommended to be ~5 years. A case study of three elevated tanks in Brookfield, Wisconsin, documented cleaning intervals of 15 years for one closed reservoir, and 7-year cleaning intervals for the other two closed reservoir tanks. Sediment of 28 inches was found in the 15-year tank and 4-12 inches of sediment in the other two tanks. Extremely high bacteria counts were found in all tanks. (Refs. 55-58)

Deceased rat on layers of sediment in a covered reservoir. Common entry points for rodents, cats, and birds in covered reservoirs are hatch or access openings, vent pipes, structural cracks, and overflow pipes. (Ref. 58)

H. Public Health Record of Portland's Open Reservoirs and Bull Run Watershed

Provided below are recent and supportive open reservoir engineering assessments and scientifically supported answers for the community's understanding of the public health benefits of open reservoirs.

Condition of open reservoirs at Mt. Tabor Park – 2009 Report
The Mt. Tabor Park Reservoirs' structures and buildings are considered nationally significant as part of an early design for a city's open water storage system. The system is historically significant for its initial construction and subsequent additions involving monumental civic undertakings, for the exemplification of early concrete engineering construction technology, and for its architectural design. As recognition of their historic significance, the buildings, structures, and site were nominated to the National Register of Historic Places and received designation as the Mt. Tabor Park Reservoirs Historic District on January 15, 2004. Generally, those features within the district boundary that date from the initial construction in 1894 through construction and additions dating to 1951 are considered historic contributing.

As viewed from a historic resource perspective, the Mt. Tabor Park Reservoirs Historic District are, for the most part, in good condition. The structures and buildings were carefully designed and were built for durability and low maintenance. Those considerations have allowed the structures to age gracefully. The facilities are currently used on a daily basis.

Very few original construction components have been lost or removed. There have been minor modifications to the facilities to allow continued operation. In many cases, these alterations, such as new electronic measuring or pipe controls, supplement the historic resources instead of replacing them. The most significant deterioration is found at the oldest facility, Reservoir No. 1, where the decorative concrete finishes on the site wall and gate house are deteriorated. Some components have been recently renovated, such as painting of the wrought iron fencing assembly located around Reservoirs No. 1 and No. 5. Other components, such as roofing, are currently in serviceable condition but will need to be replaced shortly. Still other features may be advised to be replaced for restoration purposes. (Ref. 59)

The general summary of the facilities being in good condition reflects the strong construction and engineering principles of 100 years ago. Attending to deferred maintenance and some cosmetic intervention of our open reservoirs will provide many more years of reliable safe and healthy drinking water for all.

History
The City of Portland has five open reservoirs for drinking water. Three of the reservoirs are located at Mt. Tabor Park and two are located in Washington Park. Reservoir 1 at Mt. Tabor Park and Reservoirs 3 and 4 at Washington Park were all completed in 1894. Reservoirs 5 and 6 at Mt. Tabor Park were completed in 1911. All of the reservoirs are of concrete construction and reflected the best thinking of the 1890's and early 1900's from an advanced engineering perspective and from the perspective of managing a public water supply. The engineering and construction principles of our open reservoirs were ahead of their time using advanced technologies that provide safe and healthy drinking water for us today. Ernest Ransome provided specialized cold twisted metal rebar rods and innovative reinforced concrete to build the open reservoirs that have lasted over a century and will last decades longer when properly maintained.

Ernest Ransome's engineering skills that were applied to our open reservoirs are further recognized from innovative construction in the San Francisco Bay area. Ransome's two experimental buildings at Stanford University survived the 1906 San Francisco earthquake essentially without damage while the university's newer, conventional brick structures literally crumbled around them. The published analysis of Ransome's two buildings by fellow engineer John B. Leonard did much to advance the safety of buildings in post-1906 San Francisco and nationwide.

The movement to covered reservoirs came after 1946 when new jobs were needed for returning veterans. The U.S. Public Health Service and American Public Health Association made the recommendation for covered reservoirs based on health benefits that contradict earlier acknowledgements of open reservoir health benefits. (Dr. M. J. Rosenau, 1902 Harvard School of Public Health).

Covered reservoirs have security and contamination issues. Open reservoirs are cleaned 2x/year. Covered reservoirs have not provided the public health benefits open reservoirs provide. Covered

reservoirs are cleaned every five (5) years or longer allowing for sedimentation, increased disinfectant demand and disinfectant byproduct formation, and microbial issues.

> "Although the storage facility is normally an enclosed (covered) structure, numerous access points can become entry points for debris and contaminants. These pathways may include roof top access hatches and appurtenances, sidewall joints, vent and overflow piping." (EPA) (Ref. 55)

> "Microbial contamination from birds or insects is a major water quality problem in storage tanks (covered reservoirs). One tank inspection firm that inspects 60 to 75 tanks each year in Missouri and southern Illinois reports that 20 to 25 percent of tanks inspected have serious sanitary defects; and eighty to ninety percent of these tanks have various minor flaws that could lead to sanitary problems (Zelch 2002). Most of these sanitary defects stem from design problems with roof hatch systems and vents that do not provide a watertight seal. Older cathodic protection systems of the hanging type also did not provide a tight seal. When standing inside the tank, daylight can be seen around these fixtures. The gaps allow spiders, bird droppings, and other contaminants to enter the tank. (Zelch 2002) reports a trend of positive total coliform bacteria occurrences in the fall due to water turnover in tanks. Colder water enters a tank containing warm water, causing the water in the tank to turn over. The warm water that has aged in the tank all summer is discharged to the system and is often suspected as the cause of total coliform occurrences." (EPA) (Ref. 55)

The premise of covered reservoirs reducing risk has proven to be widely unfounded. Toxic and carcinogenic materials have been widely used in and on covered reservoirs. These materials are NOT used on open reservoirs.

Portland open reservoirs have not had any deaths or public health outbreaks from chemicals or microorganisms. One alleged outbreak of waterborne Giardia illness in Portland took place in 1954. However, "failure to isolate *G. lamblia* from suspect water strongly influenced investigators to reject drinking water as the possible vehicle of infection." (Ref. 60)

Water samples from the Oregon Health Authority remain within EPA standards. Viruses, Cryptosporidium, and Giardia have not been identified in Portland's open reservoirs. Algae are not a public health issue in our open reservoirs and are limited in growth from the nitrogen and phosphorous fertilizers originating from the Columbia South Shore Well field water. Bull Run water has minimal levels because there is no agricultural chemical exposure.

V. CONCLUSION

KGW News: ***"So will a closed system prevent future boil alerts?"***

David G. Shaff, Portland Water Bureau Administrator: ***"It can still happen."***

–May 25, 2014

The public health benefits of open reservoirs at Mt. Tabor Park and Washington Park are profound. Citizens of Portland have adopted and agreed to the EPA Administrators' "LT2 Rule" position: "Science will determine the ultimate outcome" and "We're just trying to get at the public health impacts and if there's a better way to do that we'll be wide open to it" of our open reservoirs. This has been historically illustrated by the City of Portland's Open Reservoir Independent Review Panel 2004 majority vote that supported retaining the open reservoirs. **The open reservoirs provide a complex ecological tapestry of benefits showing many levels of scientific interactions that must occur to retain the public health of our community.** Sunlight, water aeration, and oxygen-loving microorganisms create an ecosystem that keeps our drinking water safe and healthy.

The Portland Water Bureau just this month placed the third of three "boil water" alerts allegedly based on the bacterium Escherichia coli, blaming it on the open reservoirs. Because of a decade-long record of water distribution system deferred maintenance water quality concerns – as acknowledged by City of Portland Auditor reports – and along with a consistent breach of acceptable microbiological water sampling protocol, there can be no expectation the reservoirs are a true source of contamination. The ongoing deferred maintenance problems – cross-connection, backflow, low pressure zones, flushing taking place upstream in SE Portland, pipe breaks, biofilm and sediment build up. etc. – are more likely to have been the source of the alleged contamination event, not the open reservoirs.

Example of water pipeline biofilm & sediment accumulation from years of Portland Water Bureau deferred maintenance and system neglect as source of alleged contamination resulting in "boil-water" notice on May 23, 2014

Additionally the PWB water sampling process has no scientific basis and breaches acceptable microbiological “aseptic technique” protocol. Probability of water contamination when sampling without gloves as a barrier is extremely high and unacceptable, leading to rejection of water sample results. Hand sanitizers are not appropriate in public use situations because they do not remove dirt and organic material that can hide contaminants. (CDC 2002)

Unacceptable water sampling procedure used by the Portland Water Bureau. Sample should be rejected as there is high contamination risk due to no gloves as barrier and water stream splash

EPA water sampling procedure using gloves as contaminant barrier and controlled flow

During the last century open reservoirs throughout the United States have provided a long and well documented history of safe drinking water. Microbiological scientists in the 1800's and 1900's such as Louis Pasteur and physician John Snow furthered the understanding of healthy drinking water by unraveling the relationship between identifiable microorganisms and disease. They determined that separation of fresh drinking water from water filled with sewage is important for public health.

One of the many Bull Run system benefits is providing safe drinking water free of sewage in contrast to the previous Portland source, the increasingly contaminated Willamette River. Consistent with our open reservoirs, scientists of the 19th and early 20th centuries recognized the many benefits of sunlight in promoting public health. European scientists discovered by chance that sunlight could kill bacteria. Media grown without sunlight exposure became cloudy from organism growth, while media grown with sunlight remained clear because of organism mortality. Later experiments from the 1900's confirmed that the presence of oxygen as well as sunlight is critical to this destructive microbial process. Soon it was accepted by the scientific community: "sunlight and fresh air are the enemies of disease".

A decade of experience under the 1986 Safe Drinking Water Act revealed several areas where responsible, science-based flexibilities and a better prioritization of effort could improve protection of public health compared to the one-size-fits-all approach of the 1986 statute. (EPA 1996) As an example 1996 SDWA, Portland's open reservoirs' existence is not to be based on a "one size fits all" EPA regulation, but on their historical public health value and recognition of future chemical and microbial challenges they have successfully overcome for more than 100 years.

The central reason for maintaining Portland's open reservoirs is that they are best for public health. There is a recognized scientific need to reduce/eliminate environmental toxic and carcinogenic chemicals that have no place in drinking water. **Portland can already meet EPA microbiological standards without the corollary health hazards resulting from covered reservoirs.**

Citizens of Portland and other local Bull Run customers are addressing their concerns about added exposures of toxic and carcinogenic chemicals in their drinking water. EPA regulates 11 disinfection byproducts and now has identified +600 more chemicals present in drinking water that are of concern but are not regulated.

The open reservoirs provide the most important and critical public health benefit of the Bull Run water system. Open reservoirs ***act as a stop sign and thus a barrier to toxic and carcinogenic chemicals*** that would otherwise enter the distribution system ending up in our homes, schools, and work places. We have seen the negative air quality outcome when closed drinking water systems allow toxic aerosol gases such as radon and chloroform exposures into everyday living situations. The shower/bath induced chloroform places the household health at risk because EPA long term toxin standards are not based on children or pregnancy exposures, only adults. There is no safe level of radon and its radioactive progeny exposure in the household air and water.

Covered reservoirs cannot efficiently provide the chemical mitigation public health process of open reservoirs because they are significantly anaerobic (without oxygen), principally enclosed, and in an environment without sunlight. Because of their public health and toxic chemical mitigation shortcomings, ***covered reservoirs act like an express lane for contaminants on their way to the distribution system and into indoor plumbing systems. For the benefit of public health and continued commitment by the City of Portland to the Precautionary Principle, the open reservoirs must be retained and maintained as they are today with the addition of improved security measures.***

While all Americans now carry many synthetic chemicals in their bodies, women often have higher levels of many toxic substances than do men. Some of these chemicals, such as chloroform, have been found in maternal blood, placental tissue, and breast milk samples from pregnant women and mothers who recently gave birth. Thus, chemical contaminants are being passed on to the next generation, both prenatally and during breastfeeding. Some chemicals (e.g., radon) indirectly increase cancer risk because they can be influenced by the effect of carcinogens. Children of all ages are considerably more vulnerable than adults to increased cancer risk and other adverse effects from virtually all harmful environmental exposures. In addition, some toxics have adverse effects not only on those that can be exposed directly (including *in utero*), but on the offspring of exposed individuals.

The Portland Utility Review Board (PURB) in July 2002 voted unanimously to pursue an EPA Waiver from the Long Term 2 Enhanced Surface Water Treatment Rule. That voted position remains in force today. The Portland City Council and Portland Water Bureau to date have not followed up on that mandate. ***Council has only asked EPA "if a waiver was available?" without providing EPA with properly documented scientific evidence or reasoning. Nor has the City of Portland made a formal waiver request.***

"Science will determine ultimate outcome" has been clearly and consistently stated by the EPA regarding case-by-case application of the "LT2 Rule." Yet the Portland City Council and the Portland Water Bureau have generally ignored the primary scientific public health benefits of open reservoirs as barriers to distribution system toxic chemical contamination. Scientifically supported public health benefit examples could have been easily presented to the Oregon Health Authority (OHA) such as: sunlight UV (AWWARF 3021), nitrification mitigation (EPA 2002), and gas volatilization (radon).

The City of Portland needs to restart the process of working transparently and in good faith with Oregon's Congressional delegation, the Oregon Health Authority, the Governor's Office, and citizens of Portland familiar with the science and advocacy administrative experience in keeping the reservoirs open. The scientific information and principles outlined in this document are intended to provide the foundation for that effort.

Portland's open reservoirs utilize the principles of chemistry, physics, and microbiology to support a safe and healthy drinking water outcome that covered reservoirs cannot meet. Contemporary science is building on the new way of thinking that reduction and elimination of drinking water environmental chemical exposure is the new future of open reservoirs to provide the best outcomes for drinking water and public health.

A. Final Thought

Joe Meyer of KBOO Radio on May 10, 2011, interviewed Dr. Gary Oxman, highly-respected Multnomah County Public Health Director (retired 2013), about Portland's open reservoirs

Q. **What about Portland's current water?**
Dr. Oxman: "I think Portland's water is superb. We have a wonderful water source in Bull Run watershed. Well designed system and responsibly run system and we have excellent water."

Q. **Are there any known public health issues today?**
Dr. Oxman: "No there really aren't. If you are talking, are there diseases caused by our water – environmental diseases, chemical diseases, bacterial diseases, microbial diseases – no we have not been aware of or detected any diseases or sign of illness associated with our water system."

Q**. If Portland does cover reservoirs will you expect fewer illnesses?**
Dr. Oxman: "We are not detecting any illnesses associated with water in Portland. *No I would not expect we would get fewer illnesses after covering reservoirs.*" (emphasis added)

Q. **Anything else to say?**
Dr. Oxman: "Great drinking water system here in Portland. Levels of citizen involvement that we have in the debates, of what the directions are a very positive thing. What we need to do as a community is to come together and debate the issues honestly, debate them openly, a lot of different factors that will influence the decisions that our policy makers will make. Council and other elected officials, and I think we need to be an active part of that process, part of the gift we can give to future generations here in Portland."

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VII. APPENDICES

Appendix 1

Excerpts from City of Portland Auditor's Reports re: Portland Water Bureau

Documenting neglected maintenance and poor management that risk public health and unnecessarily increase costs

For complete copies of these reports see: City of Portland Auditor, Audit Report Index by year – http://www.portlandonline.com/Auditor/Index.cfm?c=27096

1.1 "Portland's Water Distribution System: Maintenance Program Needs Improvement"
Office of the City Auditor, Portland, Oregon, August 2004 – Report #299

"Water mains are flushed and replaced infrequently, valves receive minimal exercising and maintenance, and meters are repaired and replaced slowly. In addition, the backlog of needed repairs has grown. Although water quality and reliability have not yet been adversely affected, we believe continued decline in the maintenance of the water distribution system assets could negatively affect water service performance in the future."

"The Bureau lacks a clear and comprehensive maintenance plan, complete and reliable information on the nature and condition of its assets, and adequate methods to organize and schedule maintenance work."

"The AWWA indicates that periodic flushing of main water lines is needed to remove bacteriological growth, sediment, and corrosion, to improve flow, and to introduce fresh water with higher chlorine residual. The most effective form of flushing is unidirectional flushing, which entails comprehensive flushing of large areas of pipe in order to systematically cleanse the pipes of debris. The Bureau's ability to perform unidirectional flushing is also hampered because the Bureau does not regularly exercise and maintain valves and does not have a complete and accurate inventory of valve status and location."

"The feet of mains replaced dropped from 46,500 to 9,800 feet, a 79 percent decline. If main replacement continues at the same rate as the past five years, it will take the Bureau over 400 years to replace all the City's 2,000 miles of water mains."

"Fire hydrants, water meters, water valves being paved over and all being neglected by Portland Water Bureau maintenance"

"A recently completed analysis of outstanding work orders by Construction and Support supervisors indicates the work order backlog may currently represent in excess of 26,000 hours of needed repairs and maintenance."

1.2 "Spending utility ratepayer money: Not always linked to services, decision process inconsistent"
Office of the City Auditor, Portland, Oregon, March 2011 – Report #398

"The City of Portland operates water and sewer utilities, and is required by City Charter to spend ratepayer money from water and sewer operations on these utilities. Recent concerns about the use of utility ratepayer money for non-utility purposes led us to conduct this audit. Our objectives were to determine whether utility ratepayer money is used for non-utility purposes, and whether the decision making process and uses of ratepayer money are transparent to the public. The audit scope included utility ratepayer money spent by the Bureau of Environmental Services (which operates the sewer system) and the Water Bureau."

"Most City spending of ratepayer money was both related to providing a utility service and approved through the complete public budget process. However, we identified other examples where this was not the case. We found that ratepayer money spent by the City falls into three categories:

1. Ratepayer money spent for purposes directly linked to providing water and sewer services that also followed the City's complete fi nancial planning and budget process.
2. Ratepayer money spent for purposes not directly linked to providing water and sewer services, but followed the City's complete financial planning and budget process.
3. Ratepayer money spent for purposes not directly linked to providing water and sewer services, and did not follow the City's complete financial planning and budget process."

"The items to consider when making decisions regarding the spending of ratepayer money are whether the utility charges are just and equitable and based on reasonable cost-of-service principles, whether the revenue is spent on utility service related purposes, and whether the utility system is operated in an efficient and effective manner."

1.3 "Portland Water Bureau: Further advances in asset management would benefit ratepayers"
Office of the City Auditor, Portland, Oregon, June 2012 – Report #405

"Water users depend on Portland Water Bureau assets – pipelines, pump stations, tanks, and other equipment that supply homes and businesses with clean water. These physical assets are valued at $7 billion. The Bureau supplies ~100 million gallons of water a day. Asset failures such as pipe breaks could result in health emergencies and significant repair costs."

"City policy requires bureaus to maintain assets in good working order to minimize future costs of maintaining and replacing them, especially to avoid costly deferred maintenance."

We found that the Bureau has developed an overarching data management strategy, but has not yet implemented key tasks to meet general Bureau needs nor to meet specialized asset management needs. For many years the Bureau has known about its data limitations. These limitations impact the data quality used for decision-making, and the efficiency of its business processes."

“Improving data management depends on leadership, dedicated technical resources, and assigning responsibility for making data management improvements.”

“We found that although the Bureau has defined its service levels, it is not using essential service levels systematically in budgeting.”

“The Bureau has not gotten agreement from representative customers that the identified service levels are appropriate for decision making. In addition, many of its 27 defined service levels do not clearly express which service is delivered, and some are not clear about what is actually measured.”

“Without plans decisions are made on a case by case basis by individual managers and the Bureau may not perform asset maintenance repair and replacement at the best times to save costs.”

“We also found that even when the Bureau had plans for asset groups, the extent of implementing the plans was unclear. Plans were partly implemented, but lacked elements needed for accountability.”

“City of Portland Auditor’s Office recommends that Commissioner in Charge direct the Portland Water Bureau to:

- Deploy resources, formalize leadership, and develop accountability structures to implement a data management approach that meets the Bureau’s asset management needs.

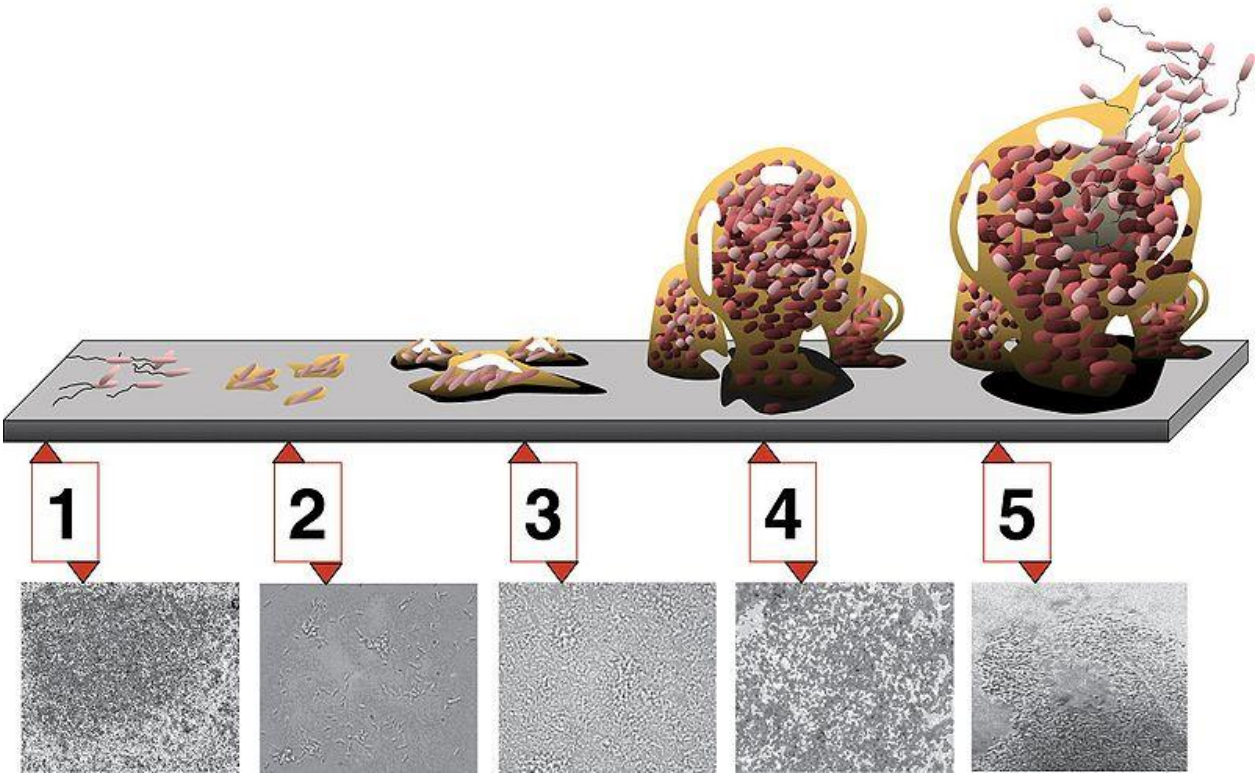
- Identify and clarify the essential required service levels, obtain confirmation from representative customers so that required service levels can be more useful in decisions about resource allocation, and apply service levels as budget criteria.

- Document management decisions and directions for action in Asset Management Plans to increase accountability and the likelihood of implementing the plans to benefit customers. Consider an overall asset management plan or other means of clarifying management policy and providing guidance for decision making.

- Incorporate an accountability framework throughout the Bureau to increase the likelihood of successfully meeting its objectives.”

Appendix 2

Portland Water Bureau Deferred Maintenance Leads to Biofilm Buildup and Puts Public Health At Risk



Process of water pipe biofilm development: 1. Attachment – 2. Permanent Attachment – 3. Maturation1 – 4. Maturation2 – 5. Dispersal of Microbes into Water System

✓ **What is biofilm in a drinking water pipe?**

Biofilm is a thin coating containing biologically active agents such as a slimy film of bacteria sticking to a surface of a structure. Biofilm has the consistency of an egg white. Some microorganisms may be primary pathogens that cause disease in healthy individuals or may be opportunistic that may affect immunocompromised individuals. (1) (2)

✓ **How does water pipe biofilm impact water quality?**

Biofilms can negatively impact water quality by increasing in size as a result of neglected water system maintenance. Colonies of biofilm bacteria continue to grow giving them protection from disinfectants such as chlorine and ammonia. Construction projects or changes in water pressure during a fire event can result in pieces of biofilm breaking off and contaminating the water system. Biofilms can also retain sediments harboring disease causing microorganisms adding to health risks if pipes are not scheduled for proper maintenance.

✓ **How does biofilm get into pipes and stay there?**

Biofilm microorganisms are present and found everywhere in a water system from the watershed to the faucet. They are part of a natural ecosystem and food chain structure except when water pipes are not properly managed.

✓ **Why do we want it removed routinely?**

Once microbial colonization of the pipe surface begins, the biofilm grows between a combination of cell division and recruitment. The microorganisms multiply and begin to draw other microorganisms into biofilm. We want to manage the biofilm volume and public health risk by routine flushing so biofilm build up does not interfere with water flow, microorganism build up, and disinfectant breakdown. City of Portland Auditor reports indicate Portland Water Bureau does not currently meet industry standards for distribution system maintenance. (3)

✓ **How does pipeline biofilm impact relate to covered reservoirs?**

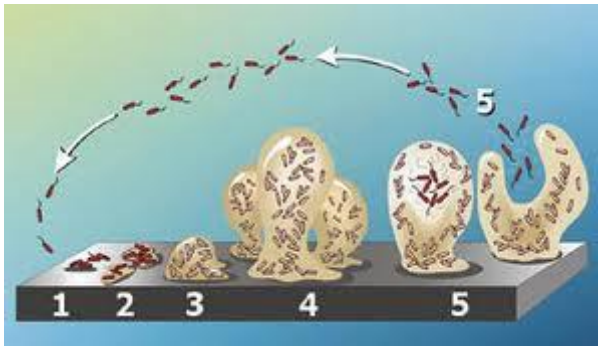
Poorly maintained water systems like Portland's have natural buildup of biofilm. As the biofilm increases because of prolonged PWB deferred maintenance chlorine demand increases leading to chloramine break down resulting in free ammonia. The free ammonia then begins to be metabolized by nitrifying bacteria leading to nitrification. Drinking water chloramine nitrification episodes in distribution systems occur in the dark (**in covered reservoirs, pipelines, taps, etc**.) leading to unwanted nitrate, nitrites, and NDMA toxic and carcinogenic chemicals. (4)

✓ **How does pipeline biofilm relate to open reservoirs**?

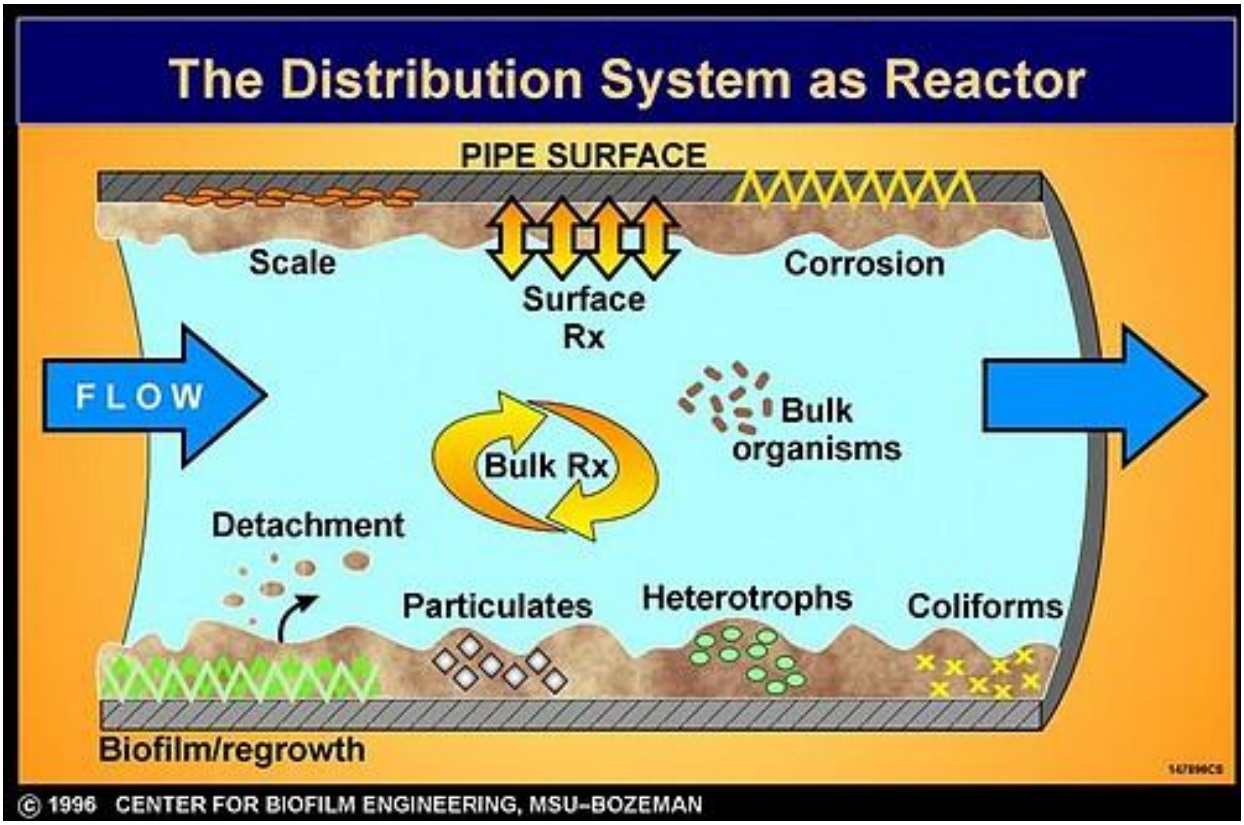
Because the open reservoirs have sunshine exposure that inhibits the bacterial nitrification process there is no relationship to the covered reservoir public health deficiencies. The sunshine also helps break down the unwanted toxic and carcinogenic chemicals; nitrates, nitrites, and NDMA that were generated in the dark pipes.

Notes:

1. Farlex Medical Dictionary, 2014
2. EPA, Health Risks from Microbial Growth and Biofilms, 2002
3. City of Portland Auditor, Portland Water Bureau Reports
4. EPA, Nitrification, 2002



Expansion of biofilm bacteria throughout unmaintained pipe system



Biofilm build up harbors disease causing microrganisms as was seen in the Fall 2013 fecal contamination event throughout the Portland drinking water system. The news story was reported by journalist Carla Castaño, KOIN 6 CBS. Illustration shows biofilm bacteria and other microorganism build up and sediment buildup on inside of water distribution system pipes

Appearance of biofilm buildup in water distribution pipes due to neglected flushing

Neglected pipe. Portland Water Bureau maintenance management has been below industry standards for more than a decade. Biofilm slime can exert a great demand for chlorine which further puts water quality and public health at risk.

Scheduled routine flushing of system can remove microorganisms. Above is an example of properly maintained water pipe that has been routinely flushed.

Appendix 3

News Report: Portland's Covered Reservoir Construction, ca. 2012–Present

Carla Castaño, journalist from KOIN 6 News, reported in February 2014 that the Powell Butte Reservoir has more than 1,000 cracks leaking thousands of gallons of water each day. Using emails from the Portland Water Bureau obtained through a public information request, KOIN 6 also learned the reservoir is four months behind schedule

Excerpts from the KOIN 6 News broadcast, "Powell Butte Reservoir failing leak tests" – Feb. 26, 2014 – http://koin.com/2014/02/26/powell-butte-reservoir-failing-leak-tests/

"It appears our reservoir leaking is increasing. We are at roughly 200,000 gallons per 24-hour day in the east and 80,000 gallons per day in the west," project manager Jim Hall wrote in one email. Hall agreed to speak with KOIN 6 News — until he spoke with the Portland Water Bureau."

"PWB has requested that all interview requests be coordinated through Tim Hall of the P-W-B," he wrote Wednesday."

"[Official PWB spokesman Tim] Hall spoke briefly with KOIN 6 News, but declined an interview. He released this statement:"

" 'Working with our contractor to find and seal these hair-width cracks is a normal and expected activity, and one of the final steps before the reservoir is put into service.' "

"Design and engineering groups who worked on reservoirs in this area told KOIN 6 News 1,200 cracks sounds like a high number and could be a design flaw. However, they also declined on-camera interviews."

"PWB said they are not over budget on the project and said they were behind schedule due to the unexpected rain."

"The Portland Water Bureau plans to have this reservoir online by March."

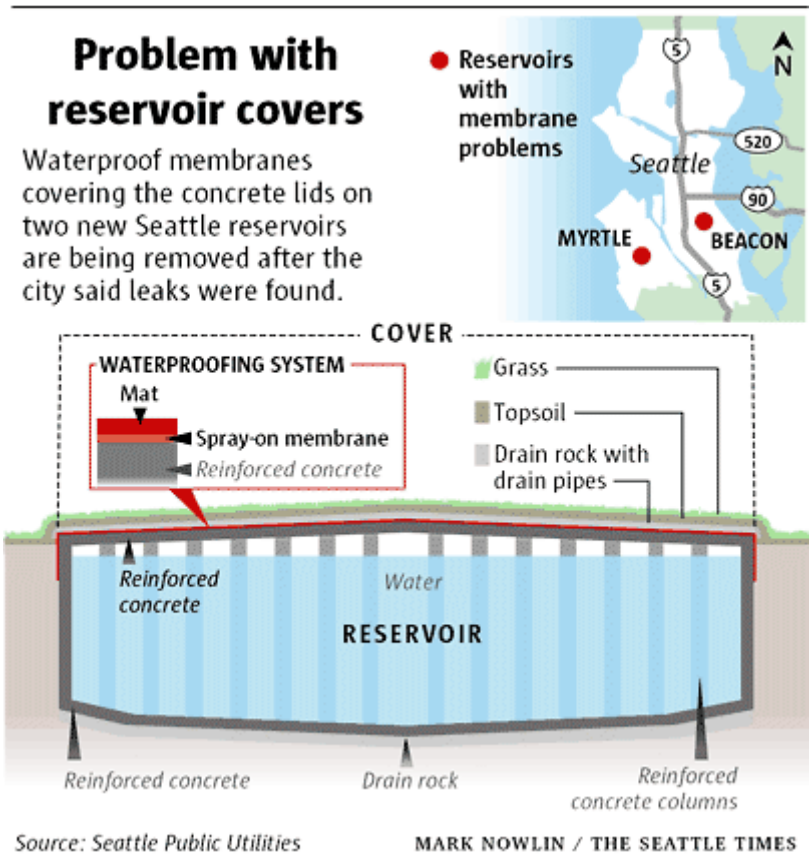
Appendix 4

News Reports: Seattle Covered Reservoirs, ca. 2009–Present

Construction concerns from poor planning and workmanship

4.1 "Major do-over for two Seattle reservoirs" – July 17, 2009
http://seattletimes.com/html/localnews/2009485902_reservoir17m.html

"As Carlos Balansay stood inside the cavernous new underground reservoir that would soon hold 50 million gallons of drinking water, the last thing the construction manager expected to see was water, dripping from a roof that was supposed to be watertight. The drops, first detected last August, have triggered a massive do-over project involving the removal of waterproof coating applied to Beacon Hill's new covered reservoir. A second new reservoir, in West Seattle, had the same orange coating applied to its concrete cover, and it, too, is being blasted off with pressure washers."



–Water proof membranes were removed and replaced with rubberized asphalt, a petrochemical that contains toxic and carcinogenic chemicals such as benzene.
–Microorganisms over time begin to biodegrade petrochemicals into smaller components that can enter drinking water through cracks.

4.2 "Hundreds of waterproofing leaks found at Myrtle, Beacon Reservoirs; 'membranes' now being dug up and redone" – July 13, 2009
http://westseattleblog.com/2009/07/wsb-exclusive-hundreds-of-waterproofing-leaks-found-at-myrtle-beacon-reservoirs-membranes-now-being-dug-up-and-redone/

"West Seattle Blog has learned that Seattle Public Utilities has ordered waterproofing work dug up and redone at two newly covered city reservoirs — Myrtle Reservoir here in West Seattle (photo) and Beacon Hill Reservoir — because of hundreds of leaks discovered in the 'membranes' applied to both projects."

4.3 "Questions over whether 4 buried reservoirs can withstand quake" – Nov. 16, 2012
http://seattletimes.com/html/localnews/2019692615_reservoirs16m.html

"Four years after discovering leaks in what were supposed to be waterproof reservoir covers, the city is investigating whether four new underground reservoirs were adequately built to withstand earthquakes."

Appendix 5

Correcting the Record: Annotated Portland Water Bureau documents

5.1 Excerpt from Portland Water Bureau Letter to the Oregon Health Authority RE: Public Health Risk Evaluation, Feb. 10, 2012

The established standard for all EPA drinking water utility decisions for years has been: "Science will determine the ultimate outcome." It is the benchmark for administering a waiver from the EPA "LT2 Rule". Yet in the case of Portland Water Bureau communications to the Oregon Health Authority to retain the open reservoirs, the relevant scientific approach to chemistry and microbiology has been consistently omitted or misstated.

In one such letter to the OHA, PWB was ostensibly making the case for the safe and reliable public health record of Portland's open reservoirs. Yet in a closing summary the PWB contradicts itself and undermines its own case with an incorrect disclaimer about the testing method used to detect microorganisms in the water samples.

Independent verification shows that AWWARF staff used a rigorous, inclusive testing method (EPA 1623 HV 1000) along with HCT 8 cell cultures during Portland's year-long "American Water Works Association Research Foundation 3021 Study" (AWWARF 3021) from 2008-09. The "HV 1000" modification of EPA's 1623 testing protocol refers to high-volume (1000-liter) samples that provide a *more* accurate assessment than standard 1623 testing. Therefore the disclaimer, shown in bold in the excerpt below, is erroneous.

Portland's AWWARF 3021 sponsored study verified zero (0) Cryptosporidium over a year-long testing period. Additionally, NO Cryptosporidium oocysts and Giardia oocysts were detected in any samples taken in 1994/1995 from Reservoir 6 and Reservoir 4 (PWB 1/28/10).

Excerpt from the PWB's 2/10/12 letter to OHA, with misleading disclaimer highlighted in bold:

> The current observable risk to public health is low. This conclusion is supported by the following:
>
> • No waterborne disease outbreaks in PWB's service area since inspections began – One criterion for maintaining a water supplier's unfiltered status is evidence that the water source "has not been the source of a waterborne disease outbreak." This criterion has been verified each year by the State of Oregon Drinking Water Program for the Bull Run source since 1991, the effective date of the Surface Water Treatment Rule.
>
> • A disease surveillance system sensitive enough to identify outbreaks – Oregon's disease surveillance, investigation, and reporting system has been used as a benchmark of excellence for foodborne outbreaks. The protocols, structures and reporting that make Oregon well-known for foodborne investigations are identical to those used for waterborne illness. Despite the challenges inherent in cryptosporidiosis surveillance, the systems in Oregon are sensitive enough to identify local outbreaks. For example, a 1998 outbreak was traced to a swimming pool in Multnomah

County. No cryptosporidiosis outbreaks in Multnomah County have ever been attributed to PWB drinking water as a source.

• Expert opinion is that the water system presents a low risk for cryptosporidiosis – A 2011 public health expert panel 10 examined the available data on cryptosporidiosis within the service area. The panel concluded that the data show no indication of an endemic disease burden due to Cryptosporidium from the water system and that no cryptosporidiosis outbreaks have ever been attributed to the Portland water supply.

• Record of safe operations – Because there is no sewage exposure in Bull Run, Portland has an outstanding record of safe operations. Yearly watershed inspections conducted by the State of Oregon since 1992 have also rated the water supply system as being in good operating condition. To ensure the continued safety of the system, many water quality parameters are monitored at the source and throughout the distribution system far more frequently than is mandated by law. In the event of a total coliform or E. coli detection, PWB has a rigorous response plan that includes a plan for notification, protocols for actions at the reservoir and in the distribution system, record-keeping, and follow-up actions.

• Water quality data collected from two of Portland's uncovered reservoirs indicated no presence of pathogenic Cryptosporidium – 36 water samples totaling 7,000 liters were collected from Reservoirs 4 and 5 between June 2008 and April 2009 as part of Water Research Foundation study 3021. **The testing method employed was not EPA Method 1623 and was instead designed to detect only the presence of infectious Cryptosporidium.** (emphasis added) Zero infectious oocysts were detected in the 36 samples.

5.2 Transcript of Very Important Letter from Friends of the Reservoirs to Portland City Council, Jan. 17, 2010

Mayor Sam Adams and City Commissioners
1120 SW Fifth Ave.
Portland, Oregon 97204-1926

RE: SDWA Open Reservoir Alternative Compliance

Dear Mayor Sam Adams and City Commissioners,

On December 16, 2009 EPA replied [1] to Commissioner Leonard's November 2009 request for clarification regarding the reservoir Variance application process. In this reply the EPA contends that the Variance provided for by Congress within the Safe Drinking Water Act (SDWA) is not available for the open reservoirs.

Ten months ago in March 2009 EPA responded in the same manner to New York City, another city seeking to retain their large Hillview open reservoir. New York was not deterred by EPA's response [2] and New York's legal team advised the Portland Water Bureau that the EPA's interpretation of the variance applicability is in fact wrong. We agree EPA is wrong.The SDWA clearly authorizes EPA to grant a variance from the LT2 "cover or treat" Cryptosporidium " treatment technique" requirement.

New York's Department of Environmental Quality spent more than a year compiling data, 161 pages, to support the retention of its Hillview reservoir. Unfortunately, during that same period of time the Portland Water Bureau focused a majority of its resources on developing and implementing fast-tracked reservoir burial projects, doing so without any public involvement.

New York City's extensive undeterred efforts to preserve their open reservoir provide a clear blueprint for action by the City of Portland. The community expectation is that the City makes a serious effort to secure the available SWDA reservoir variance, an effort evidenced in part by a Water Bureau work product. A single late-date letter to the EPA regarding a reservoir variance is not enough.

The Friends of the Reservoirs offer the following advice:

- Stop approving consultant contracts. The plan filed with the EPA in March 2009 gives YOU, City Council the power to alter the plan or the pace at which it is implemented. As noted in the fine print, the reservoir burial plan is contingent upon City Council approval of individual projects; it can be renegotiated with the EPA if the City Council does not approve the current schedule for any particular project within it.

- Require the Portland Water Bureau to prepare a detailed report documenting relevant scientific data in support of a reservoir variance.

- Seek an extension or deferral from the EPA from the burial projects. Community stakeholders have long recommended this action for both the open reservoirs and the source water requirement.

- Engage the assistance of the City Attorney and/or outside counsel Foley Hoag.

- Seek further assistance from Senator Jeff Merkley who has demonstrated his support for retention of the open reservoirs.

- Submit the data to the EPA or state of Oregon if the state has assumed Primacy for the regulation; in 2006 the state legislature unanimously approved and the Governor signed into law a state provision for variances with the full knowledge that Portland would be seeking such a variance for its open reservoirs.

- Do not rule out legislation. The opportunity for further Congressional intervention is not only possible but also likely in light of the acknowledged flaws with EPA's source water variance plan [3].

The American Water Works Association Research Foundation 3021 study preliminary report addresses the flaws of EPA's LT2. This report is discussed in the Friends of the Reservoirs September 2, 2009 letter to City Council.

In an internal EPA memo (3/31/09) addressing the reservoir applicable SDWA variance provision EPA's legal counsel states "The alternative treatment technique is available but not approvable because the only alternative EPA is aware of is a risk mitigation plan … (emphasis added)" EPA states that it wants to be consistent in its denial. Scientific data is an "approvable" way of demonstrating that our open reservoirs pose no greater risk to public health than covering or additionally treating [4].

The goal of the rule is to reduce disease incidence associated with Cryptosporidium and other disease-causing microorganisms in drinking water through "treatment techniques".

Scientific data from the recent American Water Works Association Research Association Foundation study AWWARF 3021 testing large volumes of water at the outlets of Portland's open reservoirs demonstrated that there are zero infectious Cryptosporidium in our open reservoirs. Burying, covering, or additionally treating the open reservoirs will not reduce the level of infectious Crptosporidium to below Zero. Portland's Total Coliform Rule data meets EPA standards. Our reservoirs are not subject to surface water runoff; they are cleaned twice a year.

As Commissioner Saltzman said last July about LT2, "this is a regulation in search of a problem... we should continue to pursue all alternative options beyond a large capital project."

Given the extensive scientific data in support of retaining Portland's open reservoirs, the broad-based community support for retaining our open reservoirs, the exorbitant cost of burial ($403million, $800 million with debt service) and the new public health risks [5] associated with covered reservoirs, it is incumbent on the City to push back and push back hard.

Sincerely,

Floy Jones
On behalf of The Friends of the Reservoirs

Cc Interested parties

[1] On January 12 during a Council session the community was told that a reply from the EPA on a reservoir variance had not been received; then on January 13 the Water Bureau issued a press release advising of the December 16 EPA response indicating that the original letter was somehow lost.

[2] Based on extensive review of water-quality data and other information collected by the Department of Environmental Protection, New York believes they can make the requisite showings required by the variance from the reservoir cover or additionally treat requirement. Portland's data is superior to that of New York. Portland can make the requisite showing that our open reservoirs have not caused Cryptosporidium or other drinking water related disease.

[3] EPA moved the goal post twice on the source water variance plan, which consumed more than 17 months. If EPA refuses to accept the new science that supports genotyping, confirming

whether any oocyst is harmful (dead or alive, "viability of the oocyst), and insists on sampling away from our source water out in the tributaries then further federal intervention will be necessary.

[4] While EPA has documented public health illness and deaths only with buried and covered storage, EPA failed to establish the general level of contamination in buried and covered storage thus EPA cannot factually state that buried and covered storage is more protective than open storage. See EPA white paper
http://www.epa.gov/safewater/disinfection/tcr/pdfs/whitepaper_tcr_storage.pdf

[5] EPA in its own white paper acknowledges that cancer-causing nitrification could be an unintended consequence of its LT2 reservoir requirement. Nitrification occurs in the absence of sunlight in chloraminated systems, see section 3.2 Absence of sunlight, pg.11
http://www.epa.gov/ogwdw000/disinfection/tcr/pdfs/whitepaper_tcr_nitrification.pdf

5.3 Transcript of Letter from Portland Water Bureau to the Oregon Health Authority, Aug. 23, 2011

Mr. David Leland, Program Manager
Oregon Health Authority Drinking Water Program
P.O. Box 14450
Portland, OR 97293-0450

Dear Mr. Leland:

Last Friday in a letter from Administrator Lisa Jackson, the EPA reversed its longstanding refusal to review the requirements of the federal LT2 rule as they pertain to uncovered finished drinking water reservoirs. The reversal came in response to a July 20th request from Senator Chuck Schumer to the agency.

In the letter, the EPA states:

"…as part of the Agency's Final Plan for Periodic Retrospective Review of Regulations, as well as the Safe Drinking Water Act (SDWA), the Agency will review the LT2 rule. In doing so, EPA will reassess and analyze new data and information regarding occurrence, treatment, analytical methods, health effects, and risk from viruses, Giardia, and Cryptosporidium to evaluate whether there are new or additional ways to manage risk while assuring equivalent or improved public health protection."

In light of this significant and unanticipated change in federal drinking water policy, the City requests an indefinite suspension in Portland's uncovered drinking water reservoir compliance schedule during EPA's review of the federal LT2 rule. It is critical to the City to remain in regulatory compliance with the LT2 rule during EPA's review and it therefore seeks written approval from the Oregon Health Authority Drinking Water Program of Portland's request for a suspension of the City's state approved schedule.

While it is uncertain what opportunities for alternative compliance may emerge from EPA's review, the City may choose not to proceed with its current plans for constructing additional storage at Kelly Butte until the implications of EPA's review and any subsequent changes in the federal LT2 rule are known.

Once the EPA's review is complete and Portland is given the opportunity to explore any alternative compliance methods that may become available, the City will propose a detailed amended schedule for compliance with the rule.

Please do not hesitate to contact me to discuss this matter further.

Sincerely,

David. G. Shaff
Administrator

5.4 Q&A: Refutation of Incorrect Portland Water Bureau Positions

Q1. *Why is Portland required to discontinue using the open reservoirs at Mt. Tabor Park and Washington Park?*

PWB Position – In 2006 the Environmental Protection Agency finalized the Long Term 2 Enhanced Surface Water Treatment Rule (LT2). The rule requires that water utilities discontinue the use of open finished water reservoirs or treat the water as it exits the reservoir for Cryptosporidium, Giardia, and viruses.

Correction – Since the 2004 comment period, 2006 final rule, and 2012 LT2 review, the EPA regulation has been challenged by water utilities such as New York City because it is scientifically unsupported. The EPA regulation is currently being reviewed for another two years, yet Portland City Council continues to unnecessarily fast-track closure of the safe and healthy water from the open reservoirs. City Council has replaced one reservoir with a covered reservoir that is poorly engineered and constructed that leaked millions of gallons of water per week. Cryptosporidium, viruses, and Giardia have never been detected in Portland's open reservoirs and water samples for bacteria support the safety of the water supply. Portland City Council has not referenced the public health science provided by citizens and documented in scientific literature in making its decisions about the open reservoirs.

Q2. *What about getting the "waiver" people are talking about?*

PWB Position – There is no such thing as a "waiver." When advocates speak of getting a "waiver" they are talking about legislative action by Congress to amend the federal Safe Drinking Water Act and exempt Portland from the rule which would then have to be signed by the President in order to become law. Commissioner Randy Leonard did ask our Congressional

representatives about the likelihood of obtaining legislative action on behalf of Portland and was told there was no support in Congress for such an amendment.

Correction – The "waiver" option always exists with EPA. It is a simple agreement between the EPA and the water utility. Portland has been under a "waiver" from EPA for decades under the Filtration Avoidance Determination – it is a waiver from filtering in effect today. The current situation regarding a waiver for Portland's open reservoirs is that City Council has never presented the scientific argument and formal request to EPA, as they have been repeatedly asked by advocates to do. If the "waiver" does not exist, then why are the New York City mayor, their Council and Congressional delegation asking for an EPA Waiver to keep their open reservoir? The waiver option definitely exists and is available to Portland if City Council will simply coordinate with the Oregon Health Authority to formally ask EPA for it. A waiver is the only permanent solution – Portland City Council needs to adopt the 2004 decision of Open Reservoir Independent Review Panel's majority vote outlining the well-defined scientific basis, asking for the EPA Waiver we so justifiably deserve.

Q3. *Does covered storage increase risks of gas buildup in the reservoirs?*

PWB Position – No. All reservoirs, covered or uncovered, have an air gap above the water surface that is vented into the atmosphere. For nearly 30 years, almost every customer of the Portland Water Bureau has consumed drinking water that has been stored in a covered reservoir or tank, and the water quality consistently meets or exceeds that of the open reservoirs.

Closed reservoirs, because they continue to have air exchange above the water surface, allow venting to occur. Screened vents in closed reservoirs are sized to ensure adequate air flow through the reservoir to prevent pressurization and also prevent "off-gas" buildup. Air quality has not been a problem at any of the Water Bureau's many closed reservoirs and tanks. The Water Bureau inspects and maintains vents and reservoir access points on a regular basis to prevent intrusions from animals, birds, or humans. Additionally, the State Drinking Water Program performs inspections at these sites every three years.

Correction – Another PWB answer that is false and has little scientific basis. Gas build-up such as methane in covered reservoirs has caused death from inhalation. Because covered reservoirs are so poorly maintained – being cleaned from 5-25 years – anaerobic (oxygen absent) bacteria in sediments and debris generate toxic gases. The open reservoirs acting as a barrier to toxic chemicals provide 100% efficiency and volatilization/vaporization of gases before they enter schools, homes, and businesses. Covered reservoirs cannot provide the same efficiencies in removing gasses. The vents of covered reservoirs are mostly allowing air IN to the reservoir to allow a smooth flow of water to the outlet and not allowing vacuum interference of water flow. Contrast in air efficiencies is shown by Open v. Powell Butte 2 inefficiency. For example: open reservoir at Mt. Tabor 6 is 100% efficient with open air and fountains. Powell Butte 2 at 5 acres ~ 218,000 sq. ft. with small vents at ~ 80 sq. feet opening is ~ .00037% of outside air communication venting footage efficiency.

Because of aeration, the quality of Portland's drinking water is excellent from open reservoirs. Changing to a covered drinking water system quickly degrades water quality with unwanted toxic and carcinogenic chemicals.

Q4. *Is radon an issue in Portland drinking water that will be affected by eliminating open drinking water storage?*

PWB Position – No. Radon is not detectable in Portland's main supply, the Bull Run watershed, which contributes on average over 97% of the total water supply. Radon gas naturally occurs in the western United States from underground rock formations. Portland has detectable amounts of radon it its water system from the Columbia South Shore Well Field which is used for emergency backup and to augment the Bull Run source to provide summer supply and constitutes an average of approximately 3% of the total water supply. However, these amounts do not cause the drinking water to exceed the proposed rule for radon.

Correction – Radon in drinking water at any level is very serious. EPA states "there is no safe level of radon, any exposure poses some risk of cancer."(EPA 2013) Portland receives radioactive radon water from Columbia South Shore Well field every year during maintenance or supplemental needs. CSSW can be used for emergencies at any time. Radon exposure for unknown periods of time can be expected to add public health risk entering homes, schools and work places. Radon in drinking water is not regulated by EPA. PWB does not have to disclose it exists in our water, but it is still there anyway producing radioactive materials we breathe and drink. That is why we need to retain open reservoirs for active ventilation and removal of radon gas before it enters homes, schools, and workplaces. EPA acknowledges radon to be the highest cancer causing risk of any drinking water contaminant. (EPA 1998)

Q5. *What is nitrification, and are closed reservoirs a risk in Portland's system?*

PWB Position – Nitrification is a biochemical process that in excess can interfere with the disinfection process in drinking water systems. The conditions within Portland's open finished drinking water reservoirs are more conducive to causing nitrification than the conditions within closed reservoirs. In Portland's drinking water system, the first step of the nitrification process – decomposition of chloramine disinfectant – is accelerated by loss of chlorine residual as drinking water passes through the open reservoirs. Exposure of chloraminated water over a large surface area to wind and sunlight and airborne pollutants such as pollen, dust, and animal waste has a significant role in this decomposition of the chloramines. Closed water storage facilities (i.e. tanks or covered reservoirs) do typically have the type of bacteria which are capable of feeding on ammonia and contributing to nitrification. However, without significant availability of ammonia from chloramine decomposition, or high temperatures, it is difficult for such bacteria to multiply and interfere with disinfection.

Correction – According to EPA, "consequently, nitrification episodes in distribution systems occur in the dark, i.e., in covered reservoirs, pipelines, taps, etc."(EPA 2002)

Open reservoirs inhibit nitrification, not encourage it; thus the explanation from PWB is far from truthful or accurate. Because PWB has neglected and deferred pipeline system maintenance, buildup of biofilm and sedimentation has increased the chlorine demand part of the chloramine molecule. This leads to ammonia/nitrogen exposures in the dark resulting in nitrification, as EPA has already acknowledged. Sunlight from open reservoirs disrupts the microbial nitrification process seen in the pipes and covered reservoirs. Unwanted nitrogen based chemicals like NDMA, nitrite, nitrate, etc. are also broken down by sunlight.

Q6. *What role does sunlight play in disinfection of drinking water in open reservoirs?*

PWB Position – Exposure to sunlight raises water temperatures and encourages the growth of algae and bacteria, which has been a recurring problem at open reservoirs. Sunlight can also contribute to an increase in disinfection byproducts, loss of chlorine, reduction of pH (which can cause corrosion in home plumbing), increased total coliform production, and taste and odor issues. Additionally, elevated water temperatures in the open reservoirs increases nitrification and growth of total coliforms. In highly controlled settings, processes similar to sunlight are used to provide water treatment; however, natural sunlight is not strong enough to provide demonstrable improvement in water quality. The exposure to sunlight actually has a greater number of negatives than positives. Sunlight is not a controllable treatment method, and cannot not be relied upon to adequately disinfect drinking water.

Correction – Sunlight has been recognized over the centuries as an important and valuable asset to drinking water safety and health referred to as "solar disinfection". The natural disinfection premise of open reservoirs was built on this principle. Algae and bacteria are growth based on the nutrients present such as nitrogen and phosphorous coming up from CSSW, not sunlight. Chloramine is a stronger molecule than chlorine and lasts longer in sunlight. (WHO 2004) Sunlight breaks down disinfection byproducts and other unwanted chemicals. Sunlight adds to the oxygenated water creating oxides for natural microbial control much on the principle of hydrogen peroxides. Algae are naturally present and remove acidic chemicals helping make water pH balanced. PWB's position does not align with fundamental principles of microbiology, physics, or chemistry.

"In addition surface waters are exposed to natural UV irradiation in sunlight which may damage oocyst (Cryptosporidium) DNA thereby inhibiting DNA replication and reducing infectivity." (AWWA RF 3021 2008)

Q7. *Why have waterborne disease outbreaks been associated with closed drinking water reservoirs?*

PWB Position – Portland has never had a disease outbreak caused by its closed storage reservoirs. Closed reservoirs that have had waterborne outbreaks have been in systems that experienced operational or mechanical failures and which have typically been infiltrated by animals. Open reservoirs, on the other hand, with their large water surface areas are much more vulnerable to animals entering, swimming, defecating, or dying in them. It is fairly common for Portland Water Bureau maintenance workers to find dead animals, excrement, and other contaminants in the open reservoirs – this water goes directly to the customers' tap without further treatment. Many of the documented outbreaks associated with closed reservoirs have been tracked to animals that have made their way into closed reservoirs. Animals are able to enter a closed reservoir through a broken or missing screen on its vent or overflow. Due to the screening of vents and overflow piping, evidence of animal access has never been discovered in our closed storage tanks. In Oregon, the State Drinking Water Program reviews the function of vent screens and overflows. The Water Bureau inspects and maintains vent screens and access points to its closed reservoirs and tanks on a monthly basis.

Correction – Portland's open reservoirs have never had a microbiological, chemical, or disease issue resulting in illness or death. Portland Water Bureau has never been able to demonstrate the debris they claim to find has a chain of custody originating from the open reservoirs. All we see is material placed on a tarp in the area outside the open reservoirs. Portland's open reservoirs have never had a negative impact on water quality as shown by no Cryptosporidium, viruses, or Giardia. Water samples for bacteria meet EPA and Oregon Health Authority standards. Covered reservoirs in Portland have had vandalism and dangerous chemicals thrown in them. As an example, the covered reservoir at the top of Mt. Tabor had hydrochloric acid and other debris dropped in it on May 28, 2012. This incident was never reported by Portland Water Bureau to the public.. Other covered reservoirs in Missouri and Colorado have had deaths from bacteria. Unlike the covered reservoirs, other open reservoirs across the United States do not have public health detriments either. Open reservoirs continue to provide safe and healthy drinking water for the citizens of Portland.

Q8. *What about rubberized asphalt coatings leaching into the water on a new reservoir?*

PWB Position – The new reservoirs planned at Powell Butte and Kelly Butte will be built of reinforced concrete. No rubberized asphalt coatings will be placed inside the reservoirs next to the drinking water. However, it is standard practice to apply waterproofing to the exterior of concrete structures of this type.

Correction – Rubberized asphalt is a toxic petrochemical based sealant used on concrete reservoir roofs and elsewhere on the covered reservoirs. As we have seen in the Powell Butte 2 construction, there are problems with hundreds of cracks in the roof and elsewhere. Applying the rubberized asphalt compound becomes a public health problem when it can permeate through cracks in the concrete. The caps are sealed with hot mopped coal tar that is also petrochemical based and has polycyclic aromatic hydrocarbon (PAH) cancer causing component. Rubberized asphalt has a benzene component that may be released through microbial degradation of the petrochemicals, thus reaching the drinking water through the many cracks in concrete.

These toxic component health issues are overlooked or dismissed by those who are decision makers in constructing these poorly planned and developed covered reservoirs. Standard practice in construction has little value to those who are at risk for toxic and carcinogenic chemical health issues. Rubberized asphalt is listed in California Proposition 65 as a cancer causing agent.

Q9. *Wouldn't it be cheaper to maintain the open reservoirs than build covered storage?*

PWB Position – The open reservoirs range from 100 to 117 years old. While they may look fine when full, they are in poor condition. The concrete is deteriorated, with cracks and chunks missing, the lining panels have eroded, and the steel pipes and valves are corroding. In the last 10 years $40 million dollars have been spent on reservoir maintenance, and the costs continue to climb. Perhaps most importantly, the reservoirs and pipes are not structurally sound enough to withstand an earthquake, and would be unusable for water storage at a time when they would be most needed. It has been estimated that the reservoirs would need over $125 million dollars in improvements to seismically reinforce them. This would still not meet the EPA's regulatory requirement to cover them or treat the water exiting them.

Correction – The public health benefits of the open reservoirs far outweigh the minor costs to restore and maintain them. Regular architectural and engineering reports from 1990 to 2009 confirm their condition as good with a small amount of restoration needed. The reservoirs are built soundly and have withstood earthquake activities. We reviewed the earthquake discussion during the 2004 Open Reservoir Independent Review Panel and it was confirmed that earthquakes are not a structural issue. There is no scientific or engineering reason the reservoirs cannot last many decades longer for our public health benefits. The PWB has unnecessarily spent hundreds of millions of dollars more than it would cost to maintain the open reservoirs to build covered reservoirs we do not need because water usage is declining. The engineering of Portland's open reservoirs was ahead if its time and has been shown to remain structurally solid.

Q10. *What was the AwwaRF Project 3021 sampling at Portland's open reservoirs and how does it relate to the requirements of the LT2 rule or a Variance for Open Reservoirs?*

PWB Position – In 2008 and 2009 the Portland Water Bureau participated in the Water Research Foundation (WaterRF) Project 3021, Detection of Infectious Cryptosporidium in Water. The purpose of the WaterRF project was to "examine conventionally filtered surface water for the presence of infectious Cryptosporidium using both cell culture techniques and molecular methods," and "attempt to repeat a recent study that reported a risk of infectious Cryptosporidium in filtered drinking water so that a scientifically sound consensus may be reached."

The Water Bureau's sample volumes ranged from 83.5 liters to 305.6 liters, for a total volume of about 7,000 liters during the study. Eighteen samples were collected approximately twice per month from June 2008 to April 2009. The results of the study were that no infectious Cryptosporidium oocysts were detected in any of the Water Bureau's samples. Additionally, no infectious oocysts were detected for any utility participating in this study.

EPA has indicated that variances are not available for the open reservoir requirements of LT2. Even if a variance to the open reservoir requirements of LT2 were available, the WaterRF study would not be adequate to achieve a variance.

The WaterRF study does not document the absence of Cryptosporidium and other public health risks in the open reservoirs. It simply shows that no infectious oocysts were detected in any of Portland's samples collected on 18 occasions. Given the literature that addresses the potential for direct microbial and chemical contamination and other forms of water quality degradation associated with 5 open finished water reservoirs, the data from the WaterRF study would not be considered convincing evidence for EPA, public health officials, or the scientific community in general.

Furthermore, the WaterRF study would not suffice as an adequate variance application (if one were available) for the following reasons:

1. The Water Bureau's sampling frequency and total number of samples from this study is insufficient compared to what EPA requested for the source water variance.
2. The Water Bureau's sampling location was only from Reservoir 4 (and occasionally from Reservoir 5) and not representative of all open reservoirs.
3. The WaterRF project did not use EPA Method 1623 for analysis. Method 1623 is required for LT2 monitoring.

4. LT2 samples must be analyzed by an EPA approved laboratory. The laboratory in the Texas Agrilife Research center used in the WaterRF study is not an EPA approved laboratory for Cryptosporidium.
5. The WaterRF research project did not sample for Giardia or viruses. The LT2 rule states that public water systems "using uncovered finished water storage facilities must either cover the storage facility or treat the storage facility discharge to achieve inactivation and/or removal of 4-log virus, 3-log Giardia lamblia, and 2-log Cryptosporidium." The open reservoir requirements of the LT2 rule are not solely concerned with Cryptosporidium.

Correction – In 2008 and 2009 the Portland Water Bureau participated in the American Water Works Association Research Foundation (AwwaRF) Project 3021 "Detection of Infectious Cryptosporidium in Water."

The Portland Water Bureau sampled 7000 liters at the outlet of Portland's open reservoirs with zero detects of cryptosporidium while utilizing a sampling method superior to that recommended by the EPA.

The EPA's 1623 HV sampling method has been widely criticized by municipalities and national professional associations because the agency's approved sampling method fails to distinguish between harmless and harmful Cryptosporidium, dead or alive Cryptosporidium, and between infectious and noninfectious varieties.

In a 2008 conference presentation AwwaRF 3021 researchers made this statement regarding the current EPA sampling method, "The detection of non-infectious oocysts or oocysts belonging to a species that is not infectious to humans could cause unwarranted concern for a contaminant that may not be significant public health risk."

Portland was one of 19 utilities participating in the study and, according to the study researchers; all utilities including Portland already meet the goal of the LT2 rule based on the statistically significant sampling. The goal of the LT2 rule is to reduce the level of disease in the community.

Both the Safe Drinking Water Act and Oregon state law provide for a reservoir "treatment technique" variance. It has long been recommended by community stakeholders that the Portland Water Bureau follow NYC's lead with regard to pursuing a reservoirs variance: collect and submit the AwwaRF 3021 cryptosporidium data (zero detects) along with Giardia and other necessary data to the State as part of a reservoir variance application.

Public health officials agree that there will be no measurable public health benefit from additionally "treating or covering" Portland's open reservoirs. The State Drinking Water Program now has primacy over the rule but can only consider a reservoir variance application if one is submitted. The City Council should act to ensure that the PWB applies for such a variance.* (*This statement was obtained from the Friends of the Reservoirs. The documents from the AWWA RF 3021 study have been read and agree with their position.)

"LT2 Rule" Waiver Supporters at Portland City Hall, Earth Day 2011

Moore-Love, Karla

NO Attachment

From: Kate & Chris <samsa@pacifier.com>
Sent: Thursday, April 23, 2015 2:54 AM
To: Council Clerk – Testimony; Moore-Love, Karla
Subject: Re: Cicerone Radon and Earthquakes Article--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

Please let the record show that the attached peer-reviewed Tectonophysics publication describes radon outgassing into groundwater, such as that of Portland's backup source at the Columbia South Shore Well Field, as a risk that is greatly enhanced by even slight seismic activity; such that groundwater radon concentration monitoring is a leading prognosticator of seismic events; and radon contamination can increase during events up to 12000% of baseline levels.

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

(no attachment. Resent)

Moore-Love, Karla

From:	Kate & Chris <samsa@pacifier.com>
Sent:	Thursday, April 23, 2015 2:42 AM
To:	Council Clerk – Testimony; karla.mooore-love@portlandoregon.gov
Subject:	Cicerone Radon and Earthquakes Article--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council today Thur 4/24 2 pm
Attachments:	2009-06-13 Paper--Cicerone Radon As Earthquake Detector.pdf

Dear Karla:

As part of my testimony in the above case, please enter the attached document, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

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Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

Moore-Love, Karla

From: Kate & Chris <samsa@pacifier.com>
Sent: Thursday, April 23, 2015 2:36 AM
To: Council Clerk – Testimony; Moore-Love, Karla
Subject: Re: Radon Reports--Kirkpatrick Item for the record of Washington Park land use LU-14-249689 currently scheduled as item #414 before City Council tomorrow Thur 4/24 2 pm
Attachments: 2011Portland, OR water report.pdf; 2012-PWB-DrinkingWaterQualityReport.pdf; 2013-02-13 EPA Radiation Protection Sheet on Radon.pdf

Dear Karla:

As part of my testimony in the above case, please enter the attached 2011 and 2012 Drinking Water Quality Reports, and my written testimony below, into the record for the Washington Park open reservoirs land use matter LU-14-249689 currently scheduled as item #414 before City Council today, Thursday 4/24 at 2 pm.

Please also be so kind as to send me a written receipt that this submission has been entered into the record.

Thank you!

STATEMENT OF KATHERIN KIRKPATRICK:

Dear Mayor and City Council:

Please let the record show that the radon levels in Portland's backup water source at the Columbia South Shore Well Field had shown above-action-level (> 300 pCi/L) contamination for that carcinogen for two consecutive years (2011 and 2012 Reports, attached) before the contaminant was removed from the Water Bureau's reports beginning in 2013.

Let the record show that the EPA states (2013 Protection Sheet pp 5-6, attached) that "there is no safe level of radon," which the EPA estimates to cause over a hundred unnecessary deaths per year due to "ingesting radon in water" and "inhaling radon released to the indoor air from water."

Thank you,

Katherin Kirkpatrick
1319 SE 53rd Avenue
Portland, OR 97215
(503) 232-8663
samsa@pacifier.com

http://www.epa.gov/radiation/radionuclides/radon.html
Last updated on 2/13/2013

Radiation Protection

Radon

Radon (chemical symbol Rn) is a naturally occurring radioactive gas found in soils, rock, and water throughout the U.S. It has numerous different isotopes, but radon-220, and -222 are the most common. Radon causes lung cancer, and is a threat to health because it tends to collect in homes, sometimes to very high concentrations. As a result, radon is the largest source of exposure to naturally occurring radiation.

On this page:

Reference Information

The Basics

Who Discovered Radon

The German chemist Friedrich E. Dorn discovered radon-222 in 1900, and called it radium emanation. However, a scarcer isotope, radon-220, was actually observed first, in 1899, by the British scientist, R.B. Owens, and the New Zealand scientist, Ernest Rutherford. The medical community nationwide became aware of the possible extent of a radon problem in 1984. That year a nuclear plant worker in Pennsylvania discovered radioactivity on his clothing while exiting his place of work through the radiation detectors. The source of the radiation was determined to be radon decay products on his clothing originating from his home.

Where does radon come from?

Radon-222 is the decay product of radium-226. Radon-222 and its parent, radium-226, are part of the long decay chain for uranium-238. Since uranium is essentially ubiquitous in the earth's crust, radium-226 and radon-222 are present in almost all rock and all soil and water.

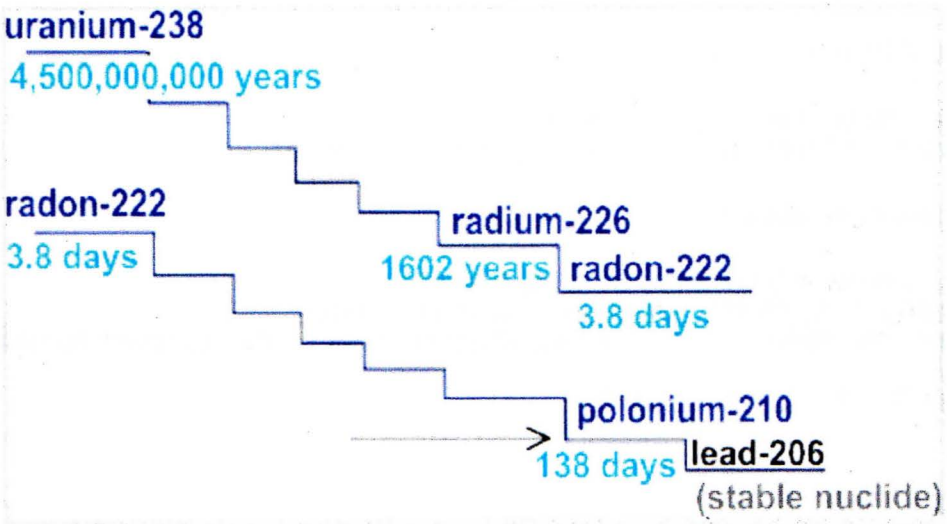
More Info

- Decay Chains - Uranium Decay
  This links provides an illustration of uranium-238 decays through a series of steps to become a stable form of lead.
- Uranium
  This fact sheet describes the basic properties and uses, and the hazards associated with this radionuclide. It also discusses radiation protection related to it.

What are the properties of radon?

Radon is a noble gas, which means it is basically *inert* (does not combine with other chemicals). Radon is a heavy gas and tends to collect in basements or other low places in housing. It has no color, odor, or taste. Radon-222 is produced by the decay of radium, has a half-life of 3.8 days, and emits an alpha particle as it decays to polonium-218, and eventually to stable lead. Radon-220, is the decay product of thorium – it is sometimes called thoron, has a half-life of 54.5 seconds and emits an alpha particle in its decay to polonium-216.

The illustration below provides an overview of the uranium-238 decay chain. Radon is part of that decay chain and is produced by the radioactive decay of radium.



More Info

- Radioactive Decay
  This page explains radioactive decay chains.

Does radon have any practical uses?

Radon has little practical use. Some medical treatments have employed radon in small sealed glass tubes, called seeds, that are specially manufactured to contain the exact amount of radioactivity needed for the application. Radon spas are used extensively in Russia and Central Europe to treat a number of conditions.

Exposure to Radon

How does radon get into the environment?

Radon-222 is the radioactive decay product of radium-226, which is found at low concentrations in almost all rock and soil. Radon is generated in rock and soil, and it creeps through cracks or spaces between particles up to the outside air. Although outdoor concentrations of radon are typically low, about 0.4 picocuries per liter (pCi/l) of air, it can seep into buildings through foundation cracks or openings and build up to much higher concentrations indoors, if the sources are large enough.

The average indoor radon concentration is about 1.3 pCi/l of air. It is not uncommon, though, for indoor radon levels to be found in the range of 5 - 50 pCi/l, and they have been found as high as 2,000 pCi/l. The concentration of radon measured in a house depends on many factors, including the design of the house, local geology and soil conditions, and the weather. Radon's decay products are all metallic solids, and when radon decay occurs in air, the decay products can cling to aerosols and dust, which makes them available for inhalation into the lungs.

Radon easily dissolves in water in areas of the country that have high radium content in soils and rocks, local ground water may contain high concentrations of radon. For example, underlying rock such as granite, or phosphate rock, typically have increased uranium and radium, and therefore radon. While radon easily dissolves into water, it also easily escapes from water when exposed to the atmosphere, especially if it is stirred or agitated. Consequently, radon concentrations are very low in rivers and lakes, but could still be high in water pumped from the ground. Some natural springs, such as those at Hot Springs, Arkansas, contain radon, and were once considered healthful.

More Info

- Radon in Water
  This site provides information Public Health Standards for Radon in Drinking Water
- Radon Home Page
  This site provides information about the hazards and management of radon.
- EPA Map of Radon Zones
  The purpose of this map is to assist National, State, and local organizations to target their resources and to implement radon-resistant building codes.

How does radon change in the environment?

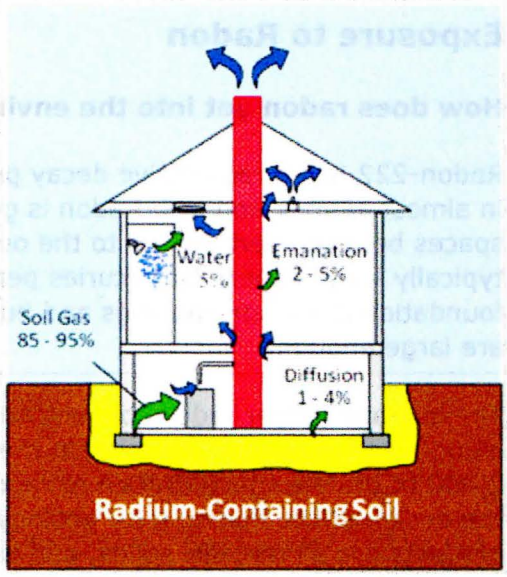
Because radon is a chemically inert (unreactive) gas, it can move easily through rock and soil and arrive at the surface. The half-life of radon-222 is 3.8 days. As it undergoes radioactive decay, radon-222 releases alpha radiation and changes to polonium-218, a short-lived

radioactive solid. After several more *transformations* (loss of particles or electromagnetic radiation from the nucleus), the series ends at lead-206, which is stable.

Radon dissolves in water, and easily leaves water that is exposed to the atmosphere, especially if the water is agitated. Consequently, radon levels are very low in rivers and lakes, but water drawn from underground can have elevated radon concentrations. Radon that decays in water, leaves only solid decay products which will remain in the water as they decay to stable lead.

How are people exposed to radon?

Most of the public's exposure to natural radiation comes from radon which can be found in homes, schools, and office buildings. The illustration at right shows the sources of radon that can accumulate in buildings.



Most radon in homes comes from radon in the soil that seeps into homes through cracks in the foundation or slab. The amount of radon in the soil varies widely and depends on the chemical make up of the soil. There can be a large difference in radon concentrations in the soil from house to house. The only way to know is to test.

Radon is also found in the water in homes, in particular, homes that have their own well rather than municipal water. When the water is agitated, as when showering or washing dishes, radon escapes into the air. However, radon from water in the home generally contributes only a small proportion (less than 5%) of the total radon in indoor air in most housing. Municipal water systems hold and treat water, which helps to release radon, so that levels are very low by the time the water reaches our homes. But, people who have private wells, particularly in areas of high radium soil content, may be exposed to higher levels of radon.

EPA estimates that the national average indoor radon level in homes is about 1.3 pCi/l of air. We also estimate that about 1 in 15 homes nationwide have levels at or above the level of 4 pCi/l, the level at which EPA recommends taking action to reduce concentrations. Levels greater than 2,000 pCi/l of air have been measured in some homes. The only way you can know if there is radon in your home is to test for it.

More Info

- Radon in Water
  This site provides information Public Health Standards for Radon in Drinking Water.
- Radon Home Page
  This site provides information about the hazards and management of radon.

How does radon get into the body?

People may ingest trace amounts of radon with food and water. However, inhalation is the main route of entry into the body for radon and its decay products. Radon decay products may attach to particulates and aerosols in the air we breathe (for example, cooking oil vapors). When they are inhaled, some of these particles are retained in the lungs. Radon decay products also cling to

Other methods may be necessary.

People who have private wells should test their well water to ensure that radon levels meet EPA's proposed standard.

More Info

- Radon in Drinking Water
  This page provides information on regulations, studies, and state contacts related to radon in drinking water.
- Radon
  This page provides access to a wide variety of information and publications on radon and preventing exposure to radon.
- National Radon Hotline:
  800.767-7236

What recommendations has the federal government made to protect human health from radon?

Since 1988, EPA and the U.S. Surgeon General have issued Health Advisories recommending that all homes be tested below the third floor for radon. They also recommended fixing homes with radon levels at or above 4 picocuries per liter (pCi/L), EPA's National Voluntary Action Level. EPA and the Surgeon General also recommend that schools nationwide be tested for radon.

More Info

- EPA Radon Publications, including:
  - EPA's "A Citizen's Guide to Radon
  - Consumer's Guide to Radon Reduction

What is EPA doing about radon?

EPA has established a voluntary program to promote radon awareness, testing, and reduction. The program sets an 'Action Level' of 4 picocuries per liter (pCi/l) of air for indoor radon. The action level is not the maximum safe level for radon in the home. However, the lower the level of radon, the better. Generally, levels can be brought below 2 pCi/l fairly simply.

In addition to working with homeowners, EPA is working with home builders and building code organizations. The goals are to help newly constructed homes be more radon resistant and to encourage radon testing when existing homes are sold.

More Info

- Radon Resistant New Construction
  This page provides information on radon resistant homes.
- Radon and Real Estate
  You will find a number of tools and resources use by the real estate community that EPA and its radon partners has developed.

The 1988 Indoor Radon Abatement Act authorizes EPA to provide grants to states to support testing and reducing radon in homes. With various non-governmental and public health organizations, EPA promotes awareness and reduction of indoor radon. Partners include the American Lung Association, the National Environmental Health Association, the American Society of Home Inspectors, and others. The page, Radon Publications and Resources, provides a list of EPA-sponsored publications in English and Spanish.

EPA has also proposed a standard for the maximum amount of radon that may be found in drinking from community water systems using ground water.

More Info

- Proposed Radon Rule
  This rule proposes maximum contaminant levels in drinking water.
- Indoor Radon Abatement Act
  This act provides grants to states to support the reduction of radon in homes.
- Radon Publications and Resources
  This is a list of EPA-sponsored publications in English and Spanish.

Understanding Radiation in Your Life, Your World

Programs · Topics · References

tobacco leaves, which are sticky, during the growing season, and enter the lungs when tobacco is smoked. Smoke in indoor environments also is very effective at picking up radon decay products from the air and making them available for inhalation. It is likely that radon decay products contribute significantly to the risk of lung cancer from cigarette smoke.

What does radon do once it gets into the body?

Most of the radon gas that you inhale is also exhaled. However, some of radon's decay products attach to dusts and aerosols in the air and are then readily deposited in the lungs. Some of these are cleared by the lung's natural defense system, and swallowed or coughed out. Those particles that are retained long enough release radiation damaging surrounding lung tissues. A small amount of radon decay products in the lung are absorbed into the blood.

Most of the radon ingested in water is excreted within hours. There is some risk from drinking water with elevated radon, because radioactive decay can occur within the body where tissues, such as the stomach lining, would be exposed. However, alpha particles emitted by radon and its decay product in water prior to drinking quickly lose their energy and are taken up by other compounds in water, and do not themselves pose a health concern.

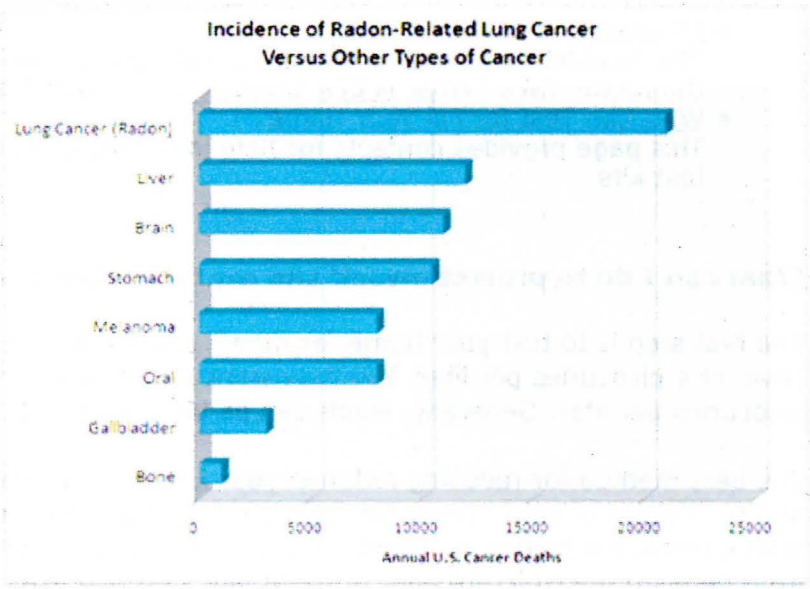
Health Effects of Radon

How can radon affect people's health?

Almost all risk from radon comes from breathing air containing radon and its decay products. The health risk of ingesting (swallowing) radon, in water for example, is much smaller than the risk of inhaling radon and its decay products.

When radon is inhaled, the alpha particles from its radioactive decay directly strike sensitive lung tissue causing damage that can lead to lung cancer. However,since radon is a gas, most of it is exhaled. The radiation dose comes largely from radon's decay products. They enter the lungs on dust particles that lodge in the airways of the lungs. These radionuclides decay quickly, exposing lung tissue to damage and producing other radionuclides that continue damaging the lung tissue.

There is no safe level of radon any exposure poses some risk of cancer. The National Academy of Sciences (NAS) studied and reported on the causes of lung cancer in two 1999 reports. They concluded that radon in indoor air is the second leading cause of lung cancer in the U.S. after cigarette smoking.



The NAS estimated that 15,000-22,000 Americans die every year from radon-related lung cancer. When people who smoke are exposed to radon as well, the risk of developing lung cancer is significantly higher than the risk of

smoking alone. The chart at right compares lung cancer cases caused by radon to the incidence of other forms of cancer.

The NAS also estimated that radon in drinking water causes an additional 180 cancer deaths per year. However, almost 90% of those deaths were from lung cancer caused by inhaling radon released to the indoor air from water. Only about 10% of the deaths were from cancers of internal organs, mostly the stomach, caused by ingesting radon in water.

Is there a medical test to determine exposure to radon?

Several decay products can be detected in urine, blood, and lung and bone tissue. However, these tests are not generally available through typical medical facilities. Also, they cannot be used to determine accurate exposure levels, since most radon decay products deliver their dose and decay within a few hours.

The best way to assess exposure to radon is by measuring concentrations of radon (or radon decay products) in the air you breathe at home.

Protecting People from Radon

How do I know if there is radon in my home?

You cannot see, feel, smell, or taste radon. Testing your home is the only way to know if you and your family are at risk from radon. EPA and the Surgeon General recommend testing for radon in all homes below the third floor. EPA also recommends testing in schools.

Radon testing is inexpensive and easy to do. It should only take a few minutes of your time. Millions of Americans have already tested their homes for radon. Various low-cost, do-it-yourself test kits are available through the mail and in hardware stores and other retail outlets. You can also hire a trained contractor to do the testing for you.

More Info

- EPA Citizen's Guide to Radon
  This booklet describes commonly available tests for measuring radon concentrations in the home. (See "What is EPA Doing About Radon?".)
- Who Can Test for Fix Your Home
  This page provides contacts for help in finding qualified professionals and do-it-yourself test kits.

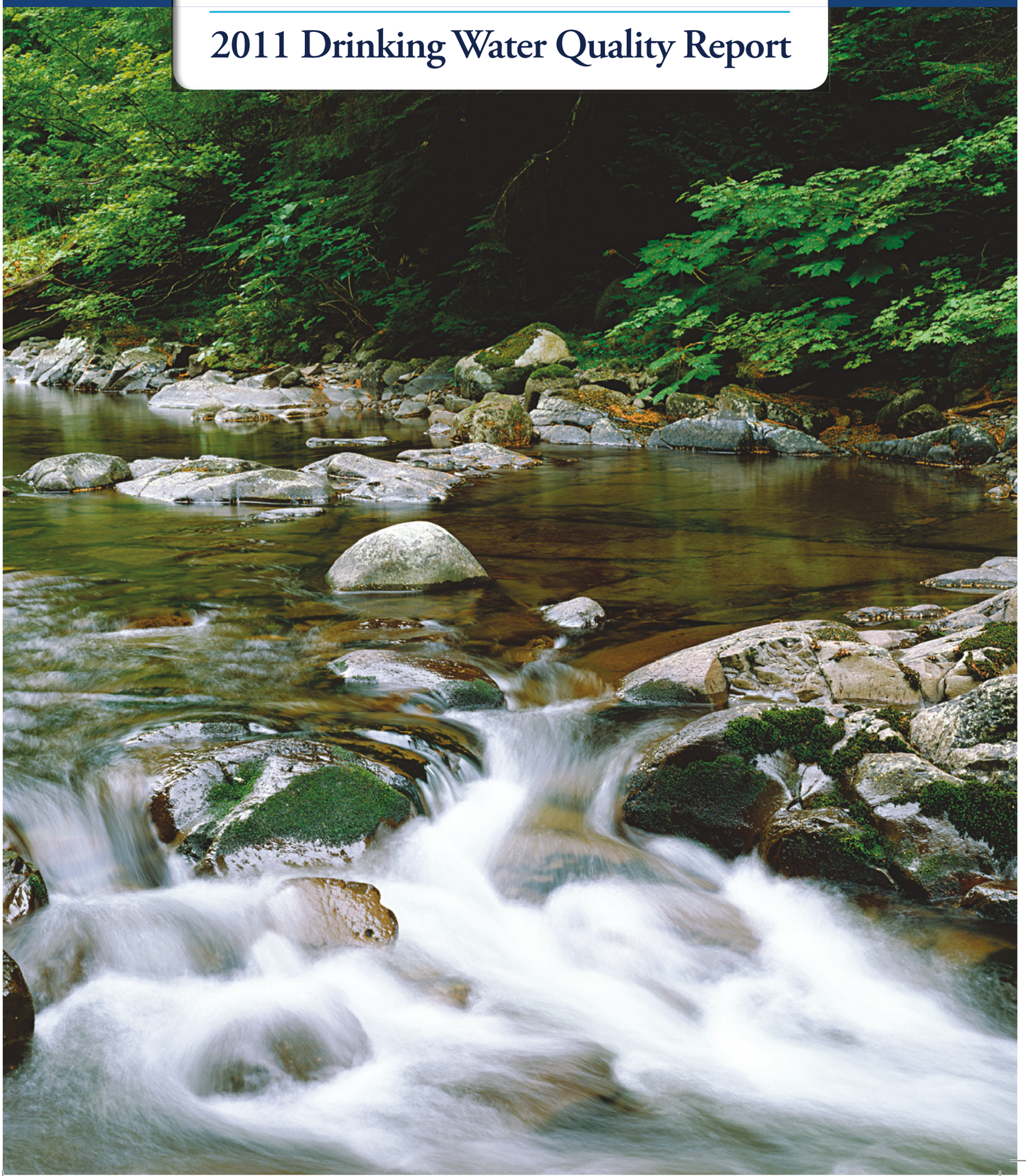
What can I do to protect myself and my family from radon?

The first step is to test your home for radon, and have it fixed if it is at or above EPA's Action Level of 4 picocuries per liter. You may want to take action if the levels are in the range of 2-4 picocuries per liter. Generally, levels can be brought below 2 pCi/l fairly simply.

The best method for reducing radon in your home will depend on how radon enters your home and the design of your home. For example, sealing cracks in floors and walls may help to reduce radon, but is not sufficient. There are also systems that remove radon from the crawl space or from beneath the concrete floor or basement slab that are effective at keeping radon from entering your home. These systems are simple and don't require major changes to your home.

PORTLAND WATER BUREAU

2011 Drinking Water Quality Report



PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

From Commissioner Randy Leonard

I am pleased to share the 2011 Drinking Water Quality Report with you. The Portland Water Bureau produces this report every year as mandated by the federal government. The report provides you with an easy-to-understand overview of your drinking water.

One thing you might note is that the Water Bureau monitors Portland's drinking water for more than 200 regulated and unregulated contaminants. That makes me feel incredibly confident in the water we serve and the water you drink. Portland's water is some of the highest-quality drinking water in the world. High quality is the Water Bureau way. It's the Portland way.

I urge you to take a minute to look through this report; learn about your water system and some of what goes into delivering water to your tap. Learn why we believe, "From forest to faucet, the Portland Water Bureau delivers the best drinking water in the world!"

Randy Leonard
Commissioner-In-Charge

From the Administrator

Since 1997, the federal government has required municipal water providers to send customers a yearly report detailing their water system. This report, the 2011 Drinking Water Quality Report, is essentially the nutritional label for the substance you probably consume more than any other – water.

If you have questions or comments about this, please call Portland Water Bureau Customer Service at 503-823-7770.
We welcome your interest in Portland's water system.

David G. Shaff
Administrator

Frequently Asked Questions About Water Quality

Is my water treated by filtration?

No. Bull Run water is not filtered. The Bull Run source meets the filtration avoidance criteria of the Surface Water Treatment Rule. The State approved Portland's compliance with these criteria in 1992. Portland continues to meet these criteria on an ongoing basis.

Does the Portland Water Bureau add fluoride to drinking water?

No. The Portland Water Bureau does not add fluoride to the water. Fluoride is a naturally occurring trace element in surface and groundwater. The U.S. Public Health Service and the Centers for Disease Control and Prevention consider the fluoride levels in Portland's water sources to be lower than optimal for the prevention of tooth decay. You may want to consult with your dentist about fluoride treatment to help prevent tooth decay, especially for young children.

Is Portland's water soft or hard?

Portland's water is very soft. The hardness of Bull Run water is typically 4-13 parts per million (ppm) – approximately ½ a grain of hardness per gallon. Portland's groundwater hardness is approximately 86 ppm (about 5 grains per gallon), which is considered moderately hard.

What is the pH of Portland's water?

The pH of Portland's drinking water typically ranges from 7.2 to 8.2.

Are sodium levels in Portland's drinking water affecting my health?

There is currently no drinking water standard for sodium. Sodium is an essential nutrient. Sodium in Portland's water typically ranges between 2 and 8 ppm, a level unlikely to contribute to adverse health effects.

Who can I call about water quality or pressure concerns?

The Water Line, **503-823-7525**, can answer your questions and concerns about water quality or pressure. The Water Line is available Monday–Friday from 8:30 a.m.– 4:30 p.m. If you have an emergency after these hours, please contact the after-hours number at **503-823-4874**.

How can I get my water tested?

Contact the LeadLine at **503-988-4000** or **www.leadline.org** for information about free lead-in-water testing. For more extensive testing, private laboratories can test your tap water for a fee. Not all labs are accredited to test for all contaminants. For information about accredited labs, call the Oregon Health Authority, Oregon Environmental Laboratory Accreditation Program at **503-693-4122**.

Public Involvement Opportunities

The Portland Water Bureau provides a variety of public information, public involvement and community outreach opportunities. If you have questions about Portland Water Bureau meetings, projects, or programs, please contact Jimmy Brown, Community Involvement and Information Manager, at **503-823-3028**, or visit the Water Blog to learn more about the bureau or leave a comment: **www.portlandoregon.gov/water/blog**.

Drinking Water Treatment

The first step in the treatment process for Portland's drinking water is disinfection using chlorine. Next, ammonia is added to form chloramines which ensure that disinfection remains adequate throughout the distribution system.

The Portland Water Bureau also adds sodium hydroxide to increase the pH of the water to reduce corrosion of plumbing systems. This treatment helps control lead and copper levels at customers' taps, should these metals be present in home plumbing.

Water Testing

The Portland Water Bureau monitors for over 200 regulated and unregulated contaminants in drinking water, including pesticides and radioactive contaminants. All monitoring data in this report are from 2010 unless otherwise noted.
If a known health-related contaminant is not listed in this report, the Portland Water Bureau did not detect it in drinking water.

Collecting groundwater samples for water quality analysis.

Special Notice for Immuno-Compromised Persons

Some people may be more vulnerable to contaminants in drinking water than the general population.

Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at-risk from infections. These people should seek advice about drinking water from their health-care providers. Environmental Protection Agency and Centers for Disease Control and Prevention guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline at **800-426-4791**.

What the EPA Says About Drinking Water Contaminants

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency's Safe Drinking Water Hotline at **800-426-4791** or at **www.epa.gov/safewater**.

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants in drinking water sources may include:

Microbial contaminants, such as viruses and bacteria, which may come from wildlife or septic systems

Inorganic contaminants, such as salts and metals, which can occur naturally or result from urban stormwater runoff, industrial or domestic wastewater discharges or farming

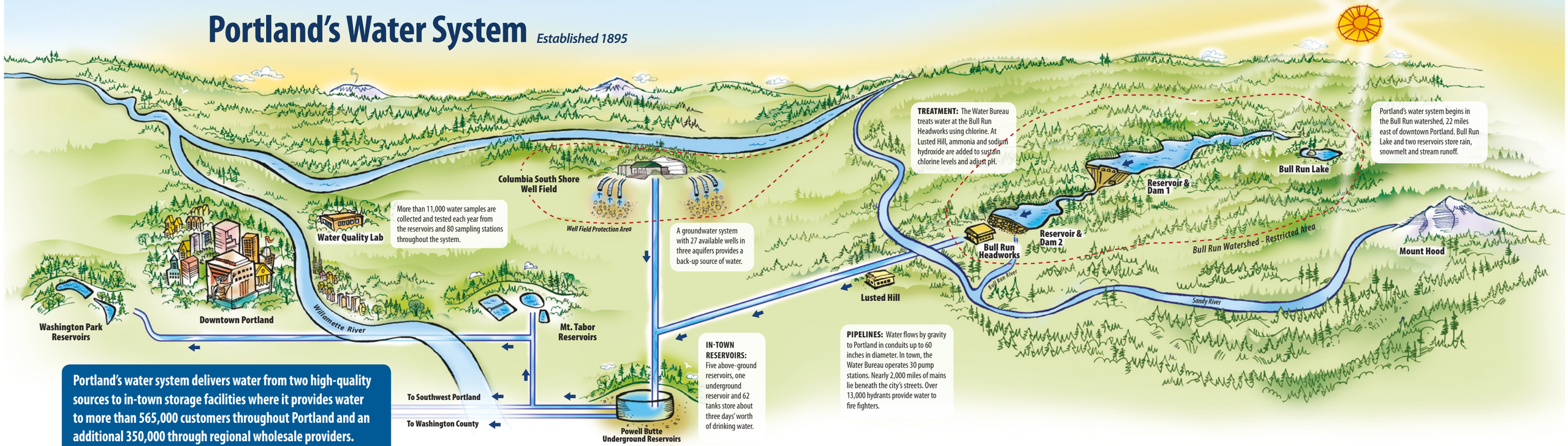
Pesticides and herbicides, which may come from a variety of sources such as farming, urban stormwater runoff and home or business use

Organic chemical contaminants, including synthetic and volatile organic chemicals, which are byproducts of industrial processes, and can also come from gas stations, urban stormwater runoff and septic systems

Radioactive contaminants, which can occur naturally

In order to ensure that tap water is safe to drink, the EPA has regulations that limit the amount of certain contaminants in water provided by public water systems and require monitoring for these contaminants. Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health.

Portland's Water System *Established 1895*



Benson Bubblers are Portland's iconic drinking fountains. The City currently maintains 52 of the four-bowl fountains and 74 one-bowl variations. The installation of the four-bowl fountains is limited to certain downtown boundaries so as not to diminish the uniqueness of them.

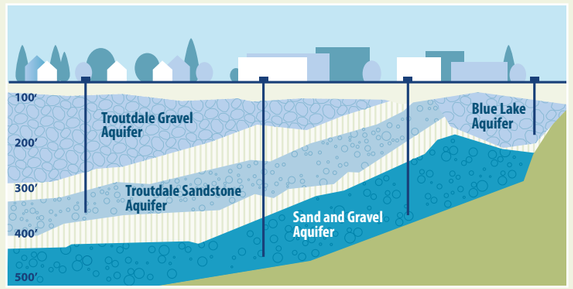
The Bull Run Watershed is a surface water supply within the Bull Run Watershed Management Unit located in the Mt. Hood National Forest. A geological ridge separates the watershed from Mount Hood. Current regulations, and the availability of the Columbia South Shore Well Field, allow Portland to meet federal drinking water standards without filtering this high-quality Bull Run water supply. The watershed has an area of 102 square miles, and typically receives 80-170 inches of rainfall a year. The heaviest rains occur from late fall through spring. Two reservoirs store water for use year-round, particularly during the dry summer months.

The watershed is only used for producing drinking water. Federal laws restrict public entry. No recreational, residential or industrial uses occur within its boundaries. The Portland Water Bureau carefully monitors water quality and quantity. The Oregon Health Authority Drinking Water Program regularly inspects the watershed and related treatment and distribution facilities.

The Portland Water Bureau has completed a Source Water Assessment for the Bull Run water supply to comply with the 1996 Safe Drinking Water Act amendments. The only contaminants of concern for the Bull Run water supply are naturally occurring microbial contaminants such as *Giardia lamblia, Cryptosporidium,* fecal coliform bacteria, and total coliform bacteria. These organisms are found in virtually all freshwater ecosystems and may be present in the Bull Run supply at very low levels. The Bull Run supply complies with all applicable state and federal regulations for source water, including the 1989 Surface Water Treatment Rule filtration-avoidance criteria. The Source Water Assessment report is available at **www.portlandoregon.gov/water** and by calling **503-823-7404**.

The Columbia South Shore Well Field provides high-quality drinking water from groundwater production wells located in three different aquifers. In 2010, the City of Portland supplemented the Bull Run drinking water supply with approximately 28 million gallons of groundwater over a 6-day period beginning on August 9th. This was done as part of a groundwater maintenance exercise.

Portland has a long history of groundwater protection. The groundwater protection area encompasses portions of Portland, Gresham and Fairview. Together, these cities regulate businesses in the groundwater protection area to prevent hazardous material spills that could seep into the ground. The cities also educate local residents on what can be done to help protect groundwater with events such as Aquifer Adventure, Cycle the Well Field and Groundwater 101. To learn more about Portland's groundwater protection program, upcoming events and how to protect groundwater, visit **www.portlandoregon.gov/water/groundwater** or call **503-823-7404**.



There are 27 usable wells capable of pumping water from three aquifers on the south shore of the Columbia River. The well field serves as a backup water supply during turbidity events and emergencies and when the bureau needs additional summer supply. The well field can produce up to 102 million gallons of water per day.

The Clackamas River Water District, City of Gresham, City of Lake Oswego, Rockwood Water People's Utility District, the Sunrise Water Authority and the Tualatin Valley Water District provide drinking water to some Portland customers who live near service area boundaries. Customers who receive water from these providers will also receive detailed water quality reports about these sources in addition to this report.

Regulated Contaminants Detected in 2010

Regulated Contaminant	Minimum Detected	Maximum Detected	Maximum Contaminant Level (MCL), Treatment Technique or Maximum Residual Disinfectant Level (MRDL)	Maximum Contaminant Level Goal (MCLG) or Maximum Residual Disinfectant Level Goal (MRDLG)	Sources of Contaminant
SOURCE WATER FROM THE BULL RUN WATERSHED					
Turbidity	0.23 NTU	2.0 NTU	Cannot exceed 5 NTU more than two times in twelve months	Not Applicable	Erosion of natural deposits
Giardia	Not Detected	8 samples of 10 liters each had 1 *Giardia* cyst	Treatment technique required: Disinfection to kill 99.9% of cysts	Not Applicable	Animal wastes
Fecal Coliform Bacteria	Not Detected	3 samples each had 4 bacterial colonies (100% of samples had 20 or fewer bacterial colonies per 100 milliliters of water)	At least 90% of samples measured during the previous six months must have 20 or fewer bacterial colonies per 100 milliliters of water	Not Applicable	Animal wastes
ENTRY POINTS TO THE DISTRIBUTION SYSTEM — from the Bull Run Watershed and Columbia South Shore Well Field					
NUTRIENTS					
Nitrate Nitrogen	0.01 parts per million	0.09 parts per million	10 parts per million	10 parts per million	Erosion of natural aquifer deposits; animal wastes
METALS AND MINERALS					
Antimony	<0.05 parts per billion	0.12 parts per billion	6 parts per billion	6 parts per billion	Found in natural deposits
Arsenic	<0.5 parts per billion	1.4 parts per billion	10 parts per billion	0 parts per billion	
Barium	0.00079 parts per million	0.00959 parts per million	2 parts per million	2 parts per million	
Chromium (total)	<0.2 parts per billion	0.3 parts per billion	100 parts per billion	100 parts per billion	
Copper[1]	<0.03 parts per million	0.0036 parts per million	Not Applicable	1.3 parts per million	
Fluoride	<0.050 parts per million	0.13 parts per million	4 parts per million	4 parts per million	
Lead	<0.02 parts per billion	0.15 parts per billion	Not Applicable	0 parts per billion	
RADIONUCLIDES					
Gross Beta[2]	3.4 picocuries per liter	3.4 picocuries per liter	50 picocuries per liter [3]	0 picocuries per liter	From man-made sources and natural deposits
DISTRIBUTION SYSTEM OF RESERVOIRS, TANKS AND MAINS					
MICROBIOLOGICAL CONTAMINANTS					
***E. Coli* Bacteria**	Not Detected	Routine samples in April and June had detectable *E. coli* bacteria	A routine sample and a repeat sample are total coliform positive, and one is also *E. coli* positive	0% of samples with detectable *E. coli* bacteria	Human and animal waste
Total Coliform Bacteria	Not Detected	6 samples out of 248 in October (2.42 %) had detectable coliform bacteria	Must not detect coliform bacteria in more than 5.0% of samples in any month	0% of samples with detectable coliform bacteria	Found throughout the environment
DISINFECTION BYPRODUCTS					
TOTAL TRIHALOMETHANES					
Running Annual Average of All Sites	21 parts per billion		80 parts per billion	Not Applicable	Byproduct of drinking water disinfection
Single Result at Any One Site	15 parts per billion	30 parts per billion	Not Applicable		
HALOACETIC ACIDS					
Running Annual Average of All Sites	25 parts per billion		60 parts per billion	Not Applicable	Byproduct of drinking water disinfection
Single Result at Any One Site	13 parts per billion	36 parts per billion	Not Applicable		
DISINFECTANT RESIDUAL					
Total Chlorine Residual	0.1 parts per million	2.2 parts per million	4 parts per million	4 parts per million	Chlorine and ammonia are used to disinfect water

Regulated Contaminant	90th Percentile Values	Number of Sites Exceeding Action Levels	Lead and Copper Rule Exceedance	Maximum Contaminant Level Goal (MCLG)	Sources of Contaminant
LEAD AND COPPER SAMPLINGS AT HIGH-RISK RESIDENTIAL WATER TAPS					
Copper	0.34 parts per million	0 of 112 samples exceeded the copper action level of 1.3 parts per million	More than 10% of the homes tested have copper levels greater than 1.3 parts per million	1.3 parts per million	Corrosion of household and commercial building plumbing systems
Lead	12 parts per billion	10 of 112 samples (8.9%) exceeded the lead action level of 15 parts per billion	More than 10% of the homes tested have lead levels greater than 15 parts per billion	0 parts per billion	Corrosion of household and commercial building plumbing systems

1 *During the year, two different methods with different method reporting limits (MRLs) were used to analyze copper. The sample with results of <0.03 was analyzed by the method with the less sensitive MRL.*

2 *These results are from 2009. The Oregon Health Authority – Drinking Water Program allows water utilities to monitor for some contaminants less than once per year because the concentrations of these contaminants do not change frequently.*

3 *The MCL for gross beta is 4 mrem/yr. EPA considers 50 picocurries per liter to be the level of concern for gross beta.*

Unregulated Contaminants Detected in 2010

Contaminant	Minimum Detected	Average Detected	Maximum Detected	Sources of Contaminant
ENTRY POINTS TO THE DISTRIBUTION SYSTEM — from the Bull Run Watershed and Columbia South Shore Well Field				
Nickel	<0.2 parts per billion	<0.2 parts per billion	0.7 parts per billion	Found in natural aquifer deposits
Radon	310 picocuries per liter	310 picocuries per liter	310 picocuries per liter	Found in natural aquifer deposits
Sodium	2.5 parts per million	8.5 parts per million	24.4 parts per million	Added to water during treatment Erosion of natural deposits
Vanadium	4.9 parts per billion	4.9 parts per billion	4.9 parts per billion	Found in natural aquifer deposits

*See **Notes on Regulated and Unregulated Contaminants** for more information.*

Definitions

Action Level
The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.

Maximum Contaminant Level or MCL
The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

Maximum Contaminant Level Goal or MCLG
The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

Maximum Residual Disinfectant Level or MRDL
The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal or MRDLG
The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Part Per Billion
One part per billion corresponds to one penny in $10,000,000 or approximately one minute in 2,000 years.

Part Per Million
One part per million corresponds to one penny in $10,000 or approximately one minute in two years. One part per million is equal to 1,000 parts per billion.

Picocuries Per Liter
Picocurie is a measurement of radioactivity. One picocurie is a trillion times smaller than one curie.

Treatment Technique
A required process intended to reduce the level of a contaminant in drinking water.

Notes on Regulated Contaminants

Turbidity
The Bull Run is an unfiltered surface water supply. The rules for public water systems have strict standards for unfiltered surface water supplies. Turbidity levels in unfiltered water must not exceed 5 NTU (nephelometric turbidity units) more than two times in a twelve-month period. The typical cause of turbidity is sediment suspended in the water that can interfere with disinfection and provide a medium for microbial growth. Large storm events can result in increased turbidity, causing the Portland Water Bureau to shut down the Bull Run system and serve water from the Columbia South Shore Well Field.

Giardia
Wildlife in the watershed may be hosts to *Giardia lamblia*, the organism that causes giardiasis. The Portland Water Bureau uses chlorine to control these organisms.

Fecal Coliform Bacteria
The presence of fecal coliform bacteria in source water indicates that water may be contaminated with animal wastes. The Portland Water Bureau uses chlorine to kill these bacteria.

Nitrate - Nitrogen
Nitrate, measured as nitrogen, can support microbial growth (bacteria and algae). Nitrate levels exceeding the standards can contribute to health problems.

Antimony, Arsenic, Barium, Chromium (total), Copper, Fluoride and Lead
These metals are elements found in the earth's crust which can dissolve into water that is in contact with natural deposits. At the levels found in Portland's drinking water, they are unlikely to contribute to adverse health effects. There is no maximum contaminant level (MCL) for copper or lead at the entry point to the distribution system. Copper and lead are regulated at customers' taps. For more information see ***Chromium-6*** on page 10 and ***Reducing Exposure to Lead*** on page 8.

Gross Beta
Certain elements are radioactive and may emit forms of radiation known as photons and beta radiation. Gross beta was detected in Portland's groundwater at the entry point to the distribution system in 2009. At levels detected in Portland's drinking water, gross beta is unlikely to contribute to adverse health effects.

***E. Coli* Bacteria**
E. coli are bacteria that indicate that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches or other symptoms. The microbes may pose a special health risk for infants, young children, some of the elderly and people with severely compromised immune systems. The Portland Water Bureau uses chlorine to kill these bacteria.

Total Coliform Bacteria
Coliforms are bacteria which are naturally present in the environment and are used as an indicator that other potentially-harmful bacteria may be present.

Disinfection Byproducts
During disinfection, certain byproducts form as a result of chemical reactions between chlorine and naturally occurring organic matter in the water. These byproducts can have negative health effects. Trihalomethanes and haloacetic acids are regulated disinfection byproducts which have been detected in Portland's water. The disinfection process is carefully controlled to keep byproduct levels low.

Total Chlorine Residual
Total chlorine residual is a measure of free chlorine and combined chlorine and ammonia in our distribution system. Chlorine residual is necessary to maintain disinfection throughout the distribution system. Adding ammonia to chlorine results in a more stable disinfectant and helps to minimize the formation of disinfection byproducts.

Notes on Unregulated Contaminants

Unregulated contaminant monitoring helps the EPA to determine where certain contaminants occur and whether it needs to regulate those contaminants in the future.

Nickel
Nickel is a metal found in the earth's crust; it can dissolve into water that is in contact with natural deposits. There is currently no maximum contaminant level for nickel. At the levels found in Portland's drinking water, it is unlikely to contribute to adverse health effects.

Radon
Radon is a naturally occurring radioactive gas that cannot be seen, tasted or smelled. Radon has not been detected in the Bull Run supply. It has been detected at varying levels in Portland's groundwater supply. For information about radon, call the EPA's Radon Hotline **(800-SOS-RADON)** or **www.epa.gov/radon/rnwater.html**.

Sodium
Sodium is a metal found in the Earth's crust; it can dissolve into water that is in contact with natural deposits or added to water during treatment. There is currently no drinking water standard for sodium. Sodium is an essential nutrient. At the levels found in drinking water, it is unlikely to contribute to adverse health effects.

Vanadium
Vanadium is a metal found in the earth's crust, which can dissolve into water that is in contact with natural deposits. Based on concerns regarding vanadium as a potential emerging contaminant, the Portland Water Bureau tested water from the Columbia South Shore Well Field for vanadium in 2010. All of the results for vanadium were below the 50 parts per billion Notification Level set by the State of California. At these levels it is unlikely to contribute to adverse health effects.

Reducing Exposure to Lead

Portland has removed all known lead service connections from its distribution system. Exposure to lead through drinking water is possible if materials in a building's plumbing contain lead. The level of lead in water can increase when water stands in contact with lead-based solder and brass faucets containing lead.

If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. The Portland Water Bureau is responsible for providing high-quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your drinking water, you may wish to request a free lead-in-water test from the LeadLine. Information on lead in drinking water, testing methods and steps you can take to minimize exposure is available from the **LeadLine, 503-988-4000**, **www.leadline.org** or the Safe Drinking Water Hotline **800-426-4791**, **www.epa.gov/safewater/lead**.

People are exposed to lead in many other ways. In the Portland area, dust from paint in homes built before 1978 is the most common source of exposure to lead. Other sources include soil, pottery, traditional folk medicines or cosmetics, some sports equipment such as fishing weights and ammunition, and some occupations and hobbies.

Corrosion Treatment

The Portland Water Bureau's corrosion control treatment reduces corrosion in plumbing by increasing the pH of the water. Comparison of monitoring results with and without pH adjustment shows more than 50 percent reduction in lead and 80 percent reduction in copper at the tap with pH adjustment.

Water Testing

Twice each year the Portland Water Bureau monitors for lead and copper in tap water from a sample group of more than 100 homes. These are homes in Portland's service area where the plumbing is known to contain lead solder which is more likely to contribute to elevated lead levels. These houses represent a worst-case scenario for lead in water. Samples are collected after the water has been standing in the household plumbing for more than 6 hours. A Lead and Copper Rule exceedance for lead occurs when more than 10 percent of these homes exceed the lead action level of 15 parts per billion. In the most recent round of testing, less than 10 percent of homes exceeded the lead action level.

If you are concerned that your home tap water may have lead, call the LeadLine for a free lead-in-water test kit and to learn ways to reduce your exposure to all sources of lead. This program targets testing the water in households most at-risk from lead in water. These are homes built between 1970 and 1985 with pregnant women or children ages six or younger in the home.

Easy steps to avoid possible exposure to lead in drinking water

- **Run your water to flush out lead.** If the water has not been used for several hours, run each tap for 30 seconds to 2 minutes or until it becomes colder before drinking or cooking. This flushes water which may contain lead from the pipes.
- **Use cold, fresh water for cooking and preparing baby formula.** Do not cook with or drink water from the hot water tap; lead dissolves more easily into hot water. Do not use water from the hot water tap to make baby formula.
- **Do not boil water to remove lead.** Boiling water will not reduce lead.
- **Consider using a filter.** Check whether it reduces lead – not all filters do. Be sure to maintain and replace a filter device in accordance with the manufacturer's instructions to protect water quality. Contact NSF International at **800-NSF-8010** or **www.nsf.org** for information on performance standards for water filters.
- **Test your water for lead.** Call the **LeadLine** at **503-988-4000** to find out how to get a **FREE** lead-in-water test.
- **Test your child for lead.** Ask your physician or call the **LeadLine** to find out how to have your child tested for lead. A blood lead level test is the only way to know whether your child is being exposed to lead.
- **Regularly clean your faucet aerator.** Particles containing lead from solder or household plumbing can become trapped in your faucet aerator. Regular cleaning every few months will remove these particles and reduce your exposure to lead.
- **Consider buying low-lead fixtures.** New brass faucets, fittings and valves, may contribute to lead in your drinking water. Federal law currently allows brass fixtures, such as faucets, to contain up to 8% lead. These fixtures are labeled as "lead-free." When buying new fixtures, consumers should seek out those with the lowest lead content. Visit **www.nsf.org** to learn more about lead content in plumbing fixtures. See ***Reduction of Lead in Drinking Water Act*** on page 10 for more information.

Leadline - 503-988-4000
Call the **LeadLine** or visit **www.leadline.org** for information about lead hazards, free lead-in-water testing, free childhood blood lead testing and referrals to other lead reduction services.

www.leadline.org

The LT2 Rule

In January 2006, the federal Environmental Protection Agency (EPA) issued a drinking water rule called the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) principally to reduce the risks of illness from *Cryptosporidium*, a protozoan parasite found in the intestines and fecal material of mammals. If ingested, infectious forms of *Cryptosporidium* can cause cryptosporidiosis which results in gastrointestinal illness in humans and more serious illness in immunocompromised populations (see ***Special Notice for Immuno-Compromised Persons*** on page 2 in this report). The LT2 rule has two principal requirements which affect Portland's water system: 1) the installation of additional treatment processes to address *Cryptosporidium* in Bull Run source water by 2014, and 2) ending the use of uncovered finished drinking water reservoirs in Mt. Tabor and Washington Parks.

Compliance with Additional Treatment Requirements

Portland's Request for a Treatment Variance

The Safe Drinking Water Act enables Portland to apply for a variance to the surface water treatment requirements of the LT2 rule if it can demonstrate that such treatment is not necessary to protect public health. In December 2009, the Water Bureau began a comprehensive water sampling program to investigate whether *Cryptosporidium* is a public health risk in the Bull Run watershed. For a one year period the City conducted intensive testing of water samples from its untreated source water. After collecting 449 water samples at the water supply intake and an additional 315 samples from several upstream watershed locations, zero instances of *Cryptosporidium* were detected. These results build on those from previous testing for *Cryptosporidium* in the Bull Run watershed. Although *Cryptosporidium* has been detected in the past, monthly tests from the watershed have not detected the pathogen since August 2002.

The absence of *Cryptosporidium* in the City's water quality sampling results is consistent with the natural conditions and legal protections in place for the Bull Run watershed which serve to reduce the risk of *Cryptosporidium* exposure for Portland's drinking water.

No Cryptosporidium *were found in the year-long water quality monitoring in support of a variance request to the treatment requirements of the LT2 rule.*

Because public entry and any associated recreational, agricultural or development activities are prohibited in the Bull Run watershed, wildlife is the only significant potential *Cryptosporidium* source in the watershed. Analysis of wildlife in the predominant old growth forest conditions in the watershed indicates that total population density of animals is relatively low and that incidence of animals shedding *Cryptosporidium* in the watershed is extremely low. From August 2009 through December 2010, the Water Bureau collected and analyzed 251 wildlife scat samples in and around the watershed for the presence of *Cryptosporidium*. Only a single sample tested positive containing just two individual *Cryptosporidium* oocysts.

Vegetation and hydrologic conditions in the watershed may further reduce the limited risk of *Cryptosporidium* contamination by restricting the movement of potential pathogens through the watershed. The dense forest canopy, low to moderate rainfall intensities, and porous soil that have a high capacity for infiltration result in most water flow occurring below the ground surface. This flow through vegetation and soil can trap pathogens, preventing them from reaching streams and the drinking water supply reservoirs.

An analysis of available health related data appears to show that the majority of the reported cases of cryptosporidiosis in the Portland region are sporadic in nature and that there was no evidence which would suggest that drinking water has been a significant source of cryptosporidiosis. This health data shows that under current conditions in the Bull Run, adding additional water treatment is not likely to result in a measurable decrease in the occurrence of reported cases of cryptosporidiosis in the Bull Run service area.

Based on these sampling results and analysis, the City intends to submit a treatment variance request to the Oregon Drinking Water Program in June 2011 and anticipates hearing back regarding its request by the end of 2011.

UV Treatment as a Last Resort

In the event the Oregon Drinking Water Program rejects the City's request for a treatment variance, the City is also in the process of designing an ultraviolet light (UV) treatment facility to meet the treatment requirements of the LT2 rule. The UV design phase is scheduled to be completed by the end of 2011 when a final decision on the City's eligibility for a treatment variance is anticipated. This timing will enable the City to meet the April 1, 2014 deadline for constructing the UV treatment facility if it proves to be necessary.

Uncovered Finished Drinking Reservoirs: Storage Replacement Underway

In November 2009, the City requested direction from EPA regarding the possibility of a variance to the uncovered finished drinking reservoir requirements of the LT2 rule. In December 2009, the EPA replied that no such option exists. As required by the LT2 Rule, the City is currently implementing a multi-year plan to develop alternative enclosed storage and end the use of its open finished drinking water reservoirs in Mt. Tabor and Washington Parks by December 31, 2020. For updates on the Portland Water Bureau's response to the LT2 rule visit **www.portlandonline.com/water/LT2**.

Developments in Water Quality

Chromium-6

The progress on research into chromium-6 made news in December 2010 when the Environmental Working Group, an environmental advocacy group, said it had found chromium-6 in the water of 31 cities and urged the EPA to adopt new rules regarding the regulation of this compound.

Currently, there are no federal regulations or requirements to test for chromium-6 in drinking water. In January 2011, the EPA issued recommendations for enhanced chromium-6 monitoring of surface water supplies quarterly and groundwater supplies semi-annually. Portland is voluntarily following these recommendations and has contracted with an accredited laboratory to conduct chromium-6 analysis of the Bull Run water supply quarterly and groundwater in summer 2011.

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium can exist in a variety of forms, but is typically found in the environment and drinking water in two main forms: trivalent chromium (chromium-3) and hexavalent chromium (chromium-6). Chromium-3 occurs naturally in the environment and is an essential human dietary nutrient. Chromium-6 is the more toxic form and is generally associated with industrial processes. Recent studies have shown that ingestion of drinking water or food containing chromium-6 may cause cancer in laboratory mice and rats. Chromium can transform from one form to another in water and soil, depending on the conditions present.

EPA's final toxicological review of chromium-6 is expected in 2011. This risk assessment will form the basis of any regulations that may be developed. PWB will continue to work closely with the EPA and with organizations such as the American Water Works Association to monitor this issue as developments emerge.

Reduction of Lead in Drinking Water Act

In December 2010, US Congress passed the Reduction of Lead in Drinking Water Act. The new law will reduce the amount of lead in new household plumbing fixtures. Currently, "lead-free" plumbing fixtures can contain up to 8% lead. Under the new law the maximum lead content allowed will be 0.25%. The new regulations only apply to new faucets and fixtures and will take effect in three years. The new law will not have any effect on existing home plumbing. The Portland Water Bureau supports the passage of this law and submitted a letter of support for passage of the bill. Household plumbing is the largest source of lead in water in the Portland area.

The Portland Water Bureau encourages customers to carefully choose new faucets and fixtures for their home. Many manufacturers are already producing components that meet the new standards. These components can most easily be purchased through retailers in California, Vermont and Maryland where the new standards have already been implemented. By 2014, all components sold in Portland will meet the higher standards.

The Portland Water Bureau has 184 water quality sampling stations throughout the distribution system to monitor water quality on a regular basis.

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CITY OF PORTLAND, OREGON
Portland Water Bureau
Commissioner Randy Leonard
Administrator David G. Shaff
1120 SW Fifth Avenue / Room 600
Portland, Oregon 97204

***************ECRWSS**
POSTAL CUSTOMER

Drinking water regulations require the city to mail this information to customers each year — It's the law.

Most of the language is also required – Congress and the EPA want to be sure that people know what is in their drinking water. The Portland Water Bureau agrees.

The Portland Water Bureau makes significant efforts to produce this complex information readable and at a low cost. ***The Portland Water Bureau produced and mailed this report for 29 cents each.***

ROMAN JOHNSTON

Dam 1 in the Bull Run watershed

Printed on recycled paper
JUNE 2011

CONTACT INFORMATION

Portland Water Bureau
1120 SW Fifth Avenue/ Room 600
Portland, Oregon 97204
www.portlandoregon.gov/water
Public Water System #4100657

Portland Water Bureau
Customer Service: 503-823-7770

Portland Water Bureau
Water Line: 503-823-7525

FOR ADDITIONAL INFORMATION

Oregon Health Authority – Drinking Water Program:
971-673-0405
www.public.health.oregon.gov/HealthyEnvironments/DrinkingWater

The City of Portland will provide auxiliary aids/services to persons with disabilities. To request an ADA accommodation, please call 503-823-7404 or by TTY at 503-823-6868. Copies of this report are available in Braille, large format type and on the Portland Water Bureau's website — www.portlandoregon.gov/water.

Spanish
Para obtener una copia de este reporte en español, por favor llame al **503-823-7770** o visite www.portlandoregon.gov/water

Russian
Чтобы получить копию этого отчета на русском языке, пожалуйста, позвоните **503-823-7770** или зайдите на сайт www.portlandoregon.gov/water

Vietnamese
Để đuợc một bản báo cáo này bằng tieng Việt, xin gọi số **503-823-7770** hoặc đến mạng lưới www.portlandoregon.gov/water

Chinese
若想获得本报告的中文版本，请拨打**503-823-7770** 或访问：www.portlandoregon.gov/water

PORTLAND WATER BUREAU

2012 Drinking Water Quality Report

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

From Commissioner Randy Leonard

I am pleased to share the 2012 Drinking Water Quality Report with you. The Portland Water Bureau produces this report every year as mandated by the federal government. The report provides you with an easy-to-understand overview of your drinking water.

One thing you might note is that the Water Bureau monitors Portland's drinking water for more than 200 regulated and unregulated contaminants. That makes me feel incredibly confident in the water we serve and the water you drink. Portland's water is some of the highest-quality drinking water in the world. High quality is the Water Bureau way. It's the Portland way.

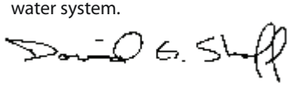
I urge you to take a minute to look through this report; learn about your water system and some of what goes into delivering water to your tap. Learn why we believe, "From forest to faucet, the Portland Water Bureau delivers the best drinking water in the world!"

Randy Leonard
Commissioner-In-Charge

From the Administrator

Since 1997, the federal government has required municipal water providers to send customers a yearly report detailing their water system. This report, the 2012 Drinking Water Quality Report, is essentially the nutritional label for the substance you probably consume more than any other – water.

If you have questions or comments about this, please call Portland Water Bureau Customer Service at 503-823-7770. We welcome your interest in Portland's water system.



David G. Shaff
Administrator

Frequently Asked Questions About Water Quality

Is my water treated by filtration?

No. Bull Run water is not filtered. The Bull Run source meets the filtration avoidance criteria of the Surface Water Treatment Rule. The State of Oregon approved Portland's compliance with these criteria in 1992. Portland continues to meet these criteria on an ongoing basis.

Does the Portland Water Bureau add fluoride to drinking water?

No. The Portland Water Bureau does not add fluoride to the water. Fluoride is a naturally occurring trace element in surface and groundwater. The U.S. Public Health Service and the Centers for Disease Control and Prevention consider the fluoride levels in Portland's water sources to be lower than optimal for the prevention of tooth decay. You may want to consult with your dentist about fluoride treatment to help prevent tooth decay, especially for young children.

Is Portland's water soft or hard?

Portland's water is very soft. The hardness of Bull Run water is typically 3-14 parts per million (ppm) – approximately ½ a grain of hardness per gallon. Portland's groundwater hardness is approximately 83 ppm (about 5 grains per gallon), which is considered moderately hard.

What is the pH of Portland's water?

The pH of Portland's drinking water typically ranges between 7.2 and 8.2.

Are sodium levels in Portland's drinking water affecting my health?

There is currently no drinking water standard for sodium. Sodium is an essential nutrient. Sodium in Portland's water typically ranges between 2 and 9 ppm, a level unlikely to contribute to adverse health effects.

Who can I call about water quality or pressure concerns?

The Water Line, **503-823-7525**, can answer your questions and concerns about water quality or pressure. The Water Line is available Monday–Friday from 8:30 a.m.– 4:30 p.m. If you have an emergency after these hours, please contact the after-hours number at **503-823-4874**.

How can I get my water tested?

Contact the LeadLine at **www.leadline.org** or **503-988-4000** for information about free lead-in-water testing. For more extensive testing, private laboratories can test your tap water for a fee. Not all labs are accredited to test for all contaminants. For information about accredited labs, call the Oregon Health Authority, Oregon Environmental Laboratory Accreditation Program at **503-693-4122**.

Public Involvement Opportunities

The Portland Water Bureau provides a variety of public information, public involvement and community outreach opportunities. If you have questions about Portland Water Bureau meetings, projects, or programs, please contact Portland Water Bureau Public Information, at 503-823-8064, or visit the Water Blog to learn more about the bureau or leave a comment: **www.portlandoregon.gov/water/blog.**

COVER PHOTO: ROMAN JOHNSTON

Drinking Water Treatment

The first step in the treatment process for Portland's drinking water is disinfection using chlorine. Next, ammonia is added to form chloramines which ensure that disinfection remains adequate throughout the distribution system.

The Portland Water Bureau also adds sodium hydroxide to increase the pH of the water to reduce corrosion of plumbing systems. This treatment helps control lead and copper levels at customers' taps, should these metals be present in home plumbing.

Water Testing

The Portland Water Bureau monitors for over 200 regulated and unregulated contaminants in drinking water, including pesticides and radioactive contaminants. All monitoring data in this report are from 2011. **If a known health-related contaminant is not listed in this report, the Portland Water Bureau did not detect it in drinking water.**

The Portland Water Bureau collects and analyzes more than 11,000 samples each year.

Special Notice for Immuno-Compromised Persons

Some people may be more vulnerable to contaminants in drinking water than the general population.

Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly people, and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health-care providers. Guidelines from the Environmental Protection Agency and Centers for Disease Control and Prevention on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline at **800-426-4791**.

What the EPA Says About Drinking Water Contaminants

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency's Safe Drinking Water Hotline at **800-426-4791** or at **www.epa.gov/safewater**.

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants in drinking water sources may include:

Microbial contaminants, such as viruses and bacteria, which may come from wildlife or septic systems

Inorganic contaminants, such as salts and metals, which can occur naturally or result from urban stormwater runoff, industrial or domestic wastewater discharges or farming

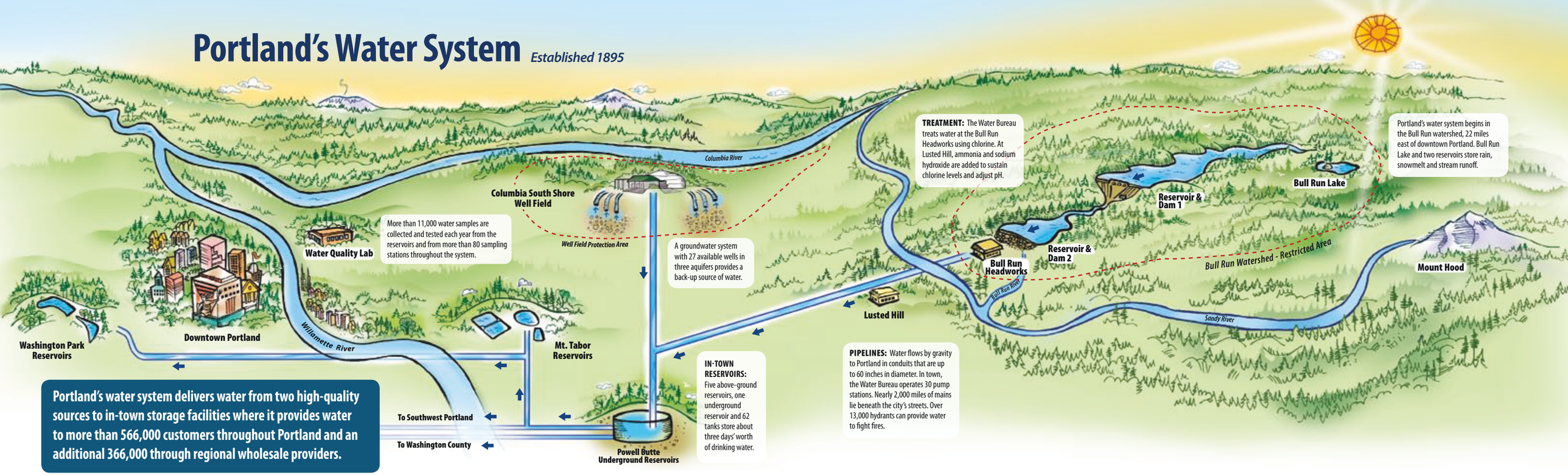
Pesticides and herbicides, which may come from a variety of sources such as farming, urban stormwater runoff and home or business use

Organic chemical contaminants, including synthetic and volatile organic chemicals, which are byproducts of industrial processes, and can also come from gas stations, urban stormwater runoff and septic systems

Radioactive contaminants, which can occur naturally

In order to ensure that tap water is safe to drink, the EPA has regulations that limit the amount of certain contaminants in water provided by public water systems and require monitoring for these contaminants. Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health.

Portland's Water System *Established 1895*



The Water Bureau maintains 18 municipal fountains throughout the Portland area. The Skidmore fountain (above), located on SW 1st Avenue between Burnside and Couch, is Portland's oldest commissioned public art, and stands at what was once the city center. Learn more at ***www.portlandonline.com/water/fountains***

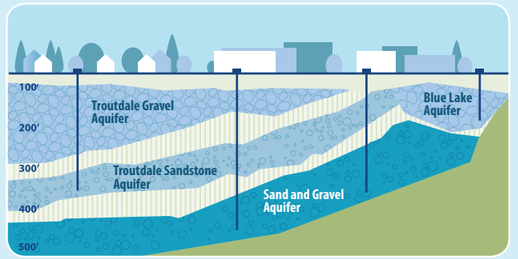
The Bull Run Watershed is a surface water supply within the Bull Run Watershed Management Unit located in the Mt. Hood National Forest. A geological ridge separates the watershed from Mount Hood. Current regulations, and the availability of the Columbia South Shore Well Field, allow Portland to meet federal drinking water standards without filtering this high-quality Bull Run water supply. The watershed has an area of 102 square miles, and typically receives 80-170 inches of rainfall a year. The heaviest rains occur from late fall through spring. Two reservoirs store water for use year-round, particularly during the dry summer months.

The watershed is used only for producing drinking water. Federal laws restrict public entry. No recreational, residential, or industrial uses occur within its boundaries. The Portland Water Bureau carefully monitors water quality and quantity. The Oregon Health Authority Drinking Water Program regularly inspects the watershed and the related treatment and distribution facilities.

The Portland Water Bureau completed a Source Water Assessment for the Bull Run water supply to comply with the 1996 Safe Drinking Water Act amendments. The only known contaminants of concern for the Bull Run water supply are naturally occurring microbial contaminants such as *Giardia lamblia, Cryptosporidium,* fecal coliform bacteria, and total coliform bacteria. These organisms are found in virtually all freshwater ecosystems and are present in the Bull Run supply at very low levels. The Bull Run supply complies with all applicable state and federal regulations for source water, including the 1989 Surface Water Treatment Rule filtration-avoidance criteria. The Source Water Assessment report is available at **www.portlandoregon.gov/water** and by calling **503-823-7404**.

The Columbia South Shore Well Field provides high-quality drinking water from groundwater production wells located in three different aquifers. In 2011, from January 16 to February 1, the Water Bureau used groundwater to provide 100 percent of the drinking water during a storm in the Bull Run watershed that resulted in increased turbidity levels. Over this 17-day period, 1.3 billion gallons of groundwater were served. In August of last year, the Water Bureau supplemented the Bull Run drinking water supply with approximately 27 million gallons of groundwater over the course of six days beginning on August 9. This was part of a groundwater maintenance operation (see page 10 for more information).

Portland has a long history of groundwater protection. In June 2008, the State of Oregon certified the Columbia South Shore Well Field Protection Plan. The protection program, encompassing portions of Portland, Gresham and Fairview, has identified commercial and industrial activities as the most significant potential sources of contamination. Together these cities regulate businesses in the groundwater protection area to prevent hazardous material spills that could seep into the ground. Events such as Aquifer Adventure, Cycle the Well Field and Groundwater 101 educate local residents on what can be done to help protect groundwater. To obtain a copy of Portland's groundwater protection program plan, which includes information on potential sources of contamination call **503-823-7404**, or to learn more about upcoming events and how to protect groundwater, visit **www.portlandonline.com/water/groundwater**.



There are 27 usable wells capable of pumping water from three aquifers on the south shore of the Columbia River. The well field serves as a backup water supply during turbidity events, emergencies and when the bureau needs additional summer supply. The well field can produce up to 102 million gallons of water per day.

The Clackamas River Water District, City of Gresham, City of Lake Oswego, Rockwood Water People's Utility District, the Sunrise Water Authority and the Tualatin Valley Water District provide drinking water to some Portland customers who live near service area boundaries. Customers who receive water from these providers will also receive detailed water quality reports about these sources in addition to this report.

Regulated Contaminants Detected in 2011

Regulated Contaminant	Minimum Detected	Maximum Detected	Maximum Contaminant Level (MCL), Treatment Technique or Maximum Residual Disinfectant Level (MRDL)	Maximum Contaminant Level Goal (MCLG) or Maximum Residual Disinfectant Level Goal (MRDLG)	Sources of Contaminant
Source Water from Bull Run Watershed					
Turbidity	0.20 NTU	4.4 NTU	Cannot exceed 5 NTU more than 2 times in 12 months	Not Applicable	Erosion of natural deposits
Total Organic Carbon	<0.5 parts per million	1.8 parts per million	Not Applicable	Not Applicable	Naturally present in the environment
Giardia lamblia	Not detected	1 sample of 10 liters had 1 *Giardia* cyst	Treatment technique required: Disinfection to kill 99.9% of cysts	Not Applicable	Animal wastes
Cryptosporidium	Not detected	1 sample of 50 liters had 1 *Cryptosporidium* oocyst	Treatment technique required by April 1, 2012	Not Applicable	Animal wastes
Fecal Coliform Bacteria	Not detected	2 samples each had 4 bacterial colonies (100% of samples had 20 or fewer bacterial colonies per 100 milliliters of water)	At least 90% of samples measured during the previous six months must have 20 or fewer bacterial colonies per 100 milliliters of water	Not Applicable	Animal wastes
Entry Points to Distribution System — from Bull Run Watershed and Columbia South Shore Well Field					
NUTRIENTS					
Nitrate - Nitrogen	<0.01 parts per million	0.14 parts per million	10 parts per million	10 parts per million	Found in natural aquifer deposits; animal wastes
METALS AND MINERALS					
Antimony	<0.05 parts per billion	0.23 parts per billion	6 parts per billion	6 parts per billion	Found in natural deposits
Arsenic	<0.5 parts per billion	1.2 parts per billion	10 parts per billion	0 parts per billion	
Barium	<0.002 parts per million	0.0079 parts per million	2 parts per million	2 parts per million	
Chromium (total)	<0.2 parts per billion	0.7 parts per billion	100 parts per billion	100 parts per billion	
Copper[1]	<0.002 parts per million	0.0009 parts per million	Not Applicable	1.3 parts per million	
Fluoride	<0.025 parts per million	0.16 parts per million	4 parts per million	4 parts per million	
Lead	<0.02 parts per billion	0.09 parts per billion	Not Applicable	0 parts per billion	

[1] *During the year, tests with varying method reporting limits (MRLs) were used to analyze copper. The sample with results of <0.002 was analyzed by the test with a less sensitive MRL; this results in data where the minimum appears to be greater than the maximum.*

Distribution System of Reservoirs, Tanks and Mains					
MICROBIOLOGICAL CONTAMINANTS					
Total Coliform Bacteria	Not Detected	3 samples out of 358 in August (0.8%) had detectable coliform bacteria	Must not detect coliform bacteria in more than 5.0% of samples in any month	0% of samples with detectable coliform bacteria	Found throughout the environment
DISINFECTION BYPRODUCTS					
Total Trihalomethanes					
Running Annual Average of All Sites	22 parts per billion		80 parts per billion	Not Applicable	Byproduct of drinking water disinfection
Single Result at Any One Site	16 parts per billion	32 parts per billion	Not Applicable		
Haloacetic Acids					
Running Annual Average of All Sites	26 parts per billion		60 parts per billion	Not Applicable	Byproduct of drinking water disinfection
Single Result at Any One Site	16 parts per billion	33 parts per billion	Not Applicable		
DISINFECTANT RESIDUAL					
Total Chlorine Residual	<0.1 parts per million	2.1 parts per million	4 parts per million	4 parts per million	Chlorine and ammonia are used to disinfect water

Regulated Contaminant	90th Percentile Values	Number of Sites Exceeding the Action Level	Lead and Copper Rule Exceedance	Maximum Contaminant Level Goal (MCLG)	Source of Contaminant
Lead and Copper Samplings at High-Risk Residential Water Taps					
Copper	0.29 parts per million	0 of 111 samples (0%) exceeded the copper action level of 1.3 parts per million	More than 10% of the homes tested have copper levels greater than 1.3 parts per million	1.3 parts per million	Corrosion of household and commercial building plumbing systems
Lead	12 parts per billion	7 of 111 samples (6%) exceeded the lead action level of 15 parts per billion	More than 10% of the homes tested have lead levels greater than 15 parts per billion	0 parts per billion	

Unregulated Contaminants Detected in 2011

Contaminant	Minimum Detected	Average Detected	Maximum Amount Detected	Source of Contaminant
Entry Points to Distribution System — from Bull Run Watershed and Columbia South Shore Well Field				
Nickel	<0.2 parts per billion	0.2 parts per billion	0.6 parts per billion	Found in natural deposits
Radon*	369 picocuries per liter	370 picocuries per liter	370 picocuries per liter	Found in natural aquifer deposits
Sodium	2.4 parts per million	7.5 parts per million	16.9 parts per million	Added to water during treatment; found in natural deposits
Vanadium*	3.3 parts per billion	3.3 parts per billion	3.3 parts per billion	Found in natural aquifer deposits

** Results are only from the entry point for the Columbia South Shore Well Field.*

*See **Notes on Regulated and Unregulated Contaminants** for more information on page 7.*

Definitions

Action Level
The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.

Maximum Contaminant Level (MCL)
The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

Maximum Contaminant Level Goal (MCLG)
The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

Maximum Residual Disinfectant Level (MRDL)
The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal (MRDLG)
The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Part Per Million (ppm)
One part per million corresponds to one penny in $10,000 or approximately one minute in two years. One part per million is equal to 1,000 parts per billion.

Part Per Billion (ppb)
One part per billion corresponds to one penny in $10,000,000 or approximately one minute in 2,000 years.

Picocuries Per Liter
Picocurie is a measurement of radioactivity. One picocurie is a trillion times smaller than one curie.

Treatment Technique
A required process intended to reduce the level of a contaminant in drinking water.

Notes on Regulated Contaminants

Turbidity
Bull Run is an unfiltered surface water supply. The rules for public water systems have strict standards for unfiltered surface water supplies. Turbidity levels in unfiltered water must not exceed 5 NTU (nephelometric turbidity units) more than two times in a twelve-month period. The typical cause of turbidity is sediment suspended in the water that can interfere with disinfection and provide a medium for microbial growth. Large storm events can result in increased turbidity, causing the Portland Water Bureau to shut down the Bull Run system and serve water from the Columbia South Shore Well Field. This occurred in early 2011, from January 16 through February 1.

Total Organic Carbon
Total Organic Carbon (TOC) is naturally found in water and can react with disinfectants to produce disinfection by-products (DBPs). The Portland Water Bureau monitors for TOC to qualify for reduced DBP monitoring. Surface water systems are eligible for reduced DBP monitoring when DBP levels are ≤ 50% of the MCL and TOC monitoring is ≤ 4.0 mg/L .

Giardia
Wildlife in the watershed may be hosts to *Giardia lamblia*, the organism that causes giardiasis. The Portland Water Bureau uses chlorine to control these organisms.

Cryptosporidium
Wildlife in the watershed may be hosts to *Cryptosporidium*, the organism that causes cryptosporidiosis. During regular monitoring for *Cryptosporidium,* a single oocyst (organism) was detected in 2011. Consultation with local health officials determined that there was no public health risk associated with the detection. This was the first detection of *Cryptosporidium* since 2002. For more information on *Cryptosporidium* and Portland's treatment variance see page 9.

Fecal Coliform Bacteria
The presence of fecal coliform bacteria in source water indicates that water may be contaminated with animal wastes. The Portland Water Bureau uses chlorine to kill these bacteria.

Nitrate - Nitrogen
Nitrate, measured as nitrogen, can support microbial growth (bacteria and algae). Nitrate levels exceeding the standards can contribute to health problems. At the levels found in Portland's drinking water, Nitrate is unlikely to contribute to adverse health effects.

Antimony, Arsenic, Barium, Chromium (total), Copper, Fluoride and Lead
These metals are elements found in the earth's crust which can dissolve into water that is in contact with natural deposits. At the levels found in Portland's drinking water source, they are unlikely to contribute to adverse health effects. There is no maximum contaminant level (MCL) for copper and lead at the entry point to the distribution system. Copper and lead are regulated at customers' taps. For more information see Chromium-6 on page 10 and Reducing Exposure to Lead on page 8.

Total Coliform Bacteria
Coliforms are bacteria which are naturally present in the environment and are used as an indicator that other potentially-harmful bacteria may be present.

Disinfection Byproducts
During disinfection, certain byproducts form as a result of chemical reactions between chlorine and naturally occurring organic matter in the water. These byproducts can have negative health effects. Trihalomethanes and haloacetic acids are regulated disinfection byproducts that have been detected in Portland's water. The disinfection process is carefully controlled to keep byproduct levels low.

Total Chlorine Residual
Total chlorine residual is a measure of free chlorine and combined chlorine and ammonia in our distribution system. Chlorine residual is necessary to maintain disinfection throughout the distribution system. Adding ammonia to chlorine results in a more stable disinfectant and helps to minimize the formation of disinfection byproducts.

Notes on Unregulated Contaminants

Unregulated contaminant monitoring helps the EPA to determine where certain contaminants occur and whether it needs to regulate those contaminants in the future.

Nickel, Sodium and Vanadium
Nickel, sodium and vanadium are metals found in the earth's crust; they can dissolve into water that is in contact with natural deposits. There are currently no maximum contaminant levels for nickel, sodium or vanadium. At the levels found in Portland's drinking water, they are unlikely to contribute to adverse health effects.

Radon
Radon is a naturally occurring radioactive gas that cannot be seen, tasted or smelled. Radon was not detected in the Bull Run supply. It has been detected at varying levels in Portland's groundwater supply. For information about radon, call the EPA's Radon Hotline **(800-SOS-RADON)** or **www.epa.gov/radon/rnwater.html**.

Reducing Exposure to Lead

Portland has removed all known lead service connections from its distribution system. Exposure to lead through drinking water is possible if materials in a building's plumbing contain lead. The level of lead in water can increase when water stands in contact with lead-based solder and brass faucets containing lead.

If present, lead at elevated levels can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. The Portland Water Bureau is responsible for providing high-quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your drinking water, you may wish to request a free lead-in-water test from the LeadLine. Information on lead in drinking water, testing methods and steps you can take to minimize exposure is available from the **LeadLine, 503-988-4000**, **www.leadline.org** or the Safe Drinking Water Hotline **800-426-4791**, **www.epa.gov/safewater/lead**.

People are exposed to lead in many other ways. In the Portland area, dust from paint in homes built before 1978 is the most common source of exposure to lead. Other sources include soil, pottery, traditional folk medicines or cosmetics, some sports equipment such as fishing weights and ammunition, and some occupations and hobbies.

Corrosion Treatment
The Portland Water Bureau's corrosion control treatment reduces corrosion in plumbing by increasing the pH of the water. Comparison of monitoring results with and without pH adjustment shows more than 50 percent reduction in lead and 80 percent reduction in copper at the tap with pH adjustment.

Water Testing
Twice each year the Portland Water Bureau monitors for lead and copper in tap water from a sample group of more than 100 homes. These are homes in the Bull Run service area where the plumbing is known to contain lead solder, which is more likely to contribute to elevated lead levels. These houses represent a worst-case scenario for lead in water. Samples are collected after the water has been standing in the household plumbing for more than 6 hours. A Lead and Copper Rule exceedance for lead occurs when more than 10 percent of these homes exceed the lead action level of 15 parts per billion. In the most recent round of testing, less than 10 percent of homes exceeded the lead action level.

If you are concerned that your home tap water may have lead, call the LeadLine for a free lead-in-water test kit and to learn ways to reduce your exposure to all sources of lead. This program targets testing the water in households most at-risk from lead in water. These are homes built between 1970 and 1985 with pregnant women or children ages six or younger in the home.

Easy steps to avoid possible exposure to lead in drinking water

- **Run your water to flush out lead.** If the water has not been used for several hours, run each tap for 30 seconds to 2 minutes or until it becomes colder before drinking or cooking. This flushes water which may contain lead from the pipes.
- **Use cold, fresh water for cooking and preparing baby formula.** Do not cook with or drink water from the hot water tap; lead dissolves more easily into hot water. Do not use water from the hot water tap to make baby formula.
- **Do not boil water to remove lead.** Boiling water will not reduce lead.
- **Consider using a filter.** Check whether it reduces lead – not all filters do. Be sure to maintain and replace a filter device in accordance with the manufacturer's instructions to protect water quality. Contact NSF International at **800-NSF-8010** or **www.nsf.org** for information on performance standards for water filters.
- **Test your water for lead.** Call the **LeadLine** at **503-988-4000** to find out how to get a **FREE** lead-in-water test.
- **Test your child for lead.** Ask your physician or call the **LeadLine** to find out how to have your child tested for lead. A blood lead level test is the only way to know whether your child is being exposed to lead.
- **Regularly clean your faucet aerator.** Particles containing lead from solder or household plumbing can become trapped in your faucet aerator. Regular cleaning every few months will remove these particles and reduce your exposure to lead.
- **Consider buying low-lead fixtures.** New brass faucets, fittings and valves, may contribute to lead in your drinking water. Federal law currently allows brass fixtures, such as faucets, to contain up to 8 percent lead. These fixtures are labeled as "lead-free." When buying new fixtures, consumers should seek out those with the lowest lead content. Visit **www.nsf.org** to learn more about lead content in plumbing fixtures.

LeadLine - 503-988-4000
Call the **LeadLine** or visit **www.leadline.org** for information about lead hazards, free lead-in-water testing, free childhood blood lead testing and referrals to other lead reduction services.
www.leadline.org

The LT2 Rule

In January 2006, the federal Environmental Protection Agency (EPA) issued the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) with the primary purpose of reducing the risks of illness from *Cryptosporidium*, a protozoan parasite found in the intestines and fecal material of most mammals. If ingested, infectious forms of *Cryptosporidium* can cause cryptosporidiosis which results in gastrointestinal illness in humans and more serious illness in immuno-compromised populations (see Special Notice for Immuno-Compromised Persons on page 2). The LT2 rule has two principal requirements that affect Portland's water system: 1) the installation of additional treatment processes to address *Cryptosporidium* in Bull Run source water, and 2) ending the use of uncovered finished drinking water reservoirs in Mt. Tabor and Washington Parks.

Compliance with Additional Treatment Requirements

Portland Achieves Treatment Variance

In December 2009, the Water Bureau began a comprehensive water sampling program and study in the Bull Run watershed to demonstrate that treatment for *Cryptosporidium* isn't necessary to protect public health. During the year-long sampling no *Cryptosporidium* was detected from the Bull Run water source. The low occurrence of *Cryptosporidium* is consistent with the natural conditions and legal protections in place for the Bull Run watershed which serve to reduce the risk of *Cryptosporidium* exposure from Portland's drinking water.

An analysis of available health-related data appears to show that drinking water is not a significant source of cryptosporidiosis. This health data shows that under current conditions in the Bull Run, adding additional water treatment is not likely to result in a measurable decrease in the occurrence of reported cases of cryptosporidiosis in the Bull Run service area.

Based on the results of the intensive sampling and analysis of the Bull Run for *Cryptosporidium*, Portland submitted a treatment variance request to the Oregon Health Authority Drinking Water Program (OHA) in June 2011. On March 14, 2012, OHA approved the City's treatment variance request establishing a 10-year period of compliance beginning on April 1, 2012, provided the City continuously meets a set of rigorous monitoring, watershed protection and reporting conditions.

The treatment variance contains important conditions that provide safeguards to protect the health of Portland customers. These conditions require Portland to continue to monitor Bull Run source water for *Cryptosporidium*, maintain all legal protections in the Bull Run, and monitor and manage any potential sources for *Cryptosporidium* contamination in the watershed. In the event of a detection of *Cryptosporidium*, the Portland Water Bureau will increase its monitoring efforts, coordinate with health officials to determine what, if any, impacts the detection may have, and communicate this information to its customers.

As a result of the variance decision, Portland will not be constructing an ultraviolet light treatment facility to achieve the treatment requirements of the LT2 rule.

Uncovered Finished Drinking Water Reservoirs:

The Portland Water Bureau submitted a plan to the EPA for complying with the covered storage requirements of the LT2 rule on March 25, 2009. The plan outlined dates for the development of replacement storage for Portland's five uncovered drinking water reservoirs by 2021.

In November 2009, the City requested direction from EPA regarding the possibility of a variance to the uncovered finished drinking reservoir requirements of the LT2 rule. In December 2009, the EPA replied that no such option existed. However, in August 2011, EPA agreed to review the uncovered reservoir requirements of the LT2 rule. Per EPA's guidance, Portland submitted a request to the OHA in February 2012, for an extension to its water storage replacement schedule that would extend the final compliance date for replacement of the uncovered reservoirs to June 2026. On May 17, 2012, OHA denied the Water Bureau's request for an adjustment to its regulatory schedule to replace the uncovered drinking water reservoirs at Mt.Tabor and Washington parks. The decision by OHA means that Portland's existing regulatory schedule to end the use of the uncovered reservoirs by December 31, 2020 remains in effect.

For updates on the Portland Water Bureau's actions regarding the LT2 rule visit **www.portlandonline.com/water/LT2**.

On March 14, 2012, the Oregon Health Authority (OHA) Drinking Water Program issued its Final Order granting a variance from the federal and state requirement that the Portland Water Bureau treat Bull Run source water for Cryptosporidium.

Developments in Water Quality

Chromium-6

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium can exist in a variety of forms, but is typically found in the environment and drinking water in two main forms: trivalent chromium (chromium-3) and hexavalent chromium (chromium-6). Chromium-3 occurs naturally in the environment and is an essential human dietary nutrient. Chromium-6 is the more toxic form and is generally associated with industrial processes. Chromium can transform from one form to another in water and soil, depending on the conditions present.

Recent studies have shown that ingestion of drinking water or food containing chromium-6 may cause cancer in laboratory mice and rats. Currently, there are no federal regulations for chromium-6 in drinking water. However, the EPA does have a standard for total chromium, of which chromium-6 is a component, at a level of 100 parts per billion (ppb) in drinking water.

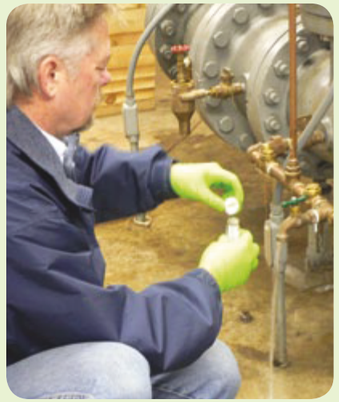
The progress on research into chromium-6 made news in December 2010 when the Environmental Working Group, an environmental advocacy group, said it had found chromium-6 in the water of 31 cities and urged the EPA to adopt new rules regarding the regulation of this compound. In January 2011, the EPA issued a recommendation that drinking water systems monitor for chromium-6 to gain a better understanding of concentrations of the contaminant present in drinking water across the country.

The Portland Water Bureau voluntarily followed EPA's guidance and sampled the Bull Run and distribution system for chromium-6 quarterly in 2011. The Columbia South Shore Well Field was also tested during the annual maintenance operation in August.

2011 Chromium-6 Results

Location	Minimum Detected[1]	Average Detected	Maximum Detected
Source water	<0.05 parts per billion	0.022 parts per billion	0.031 parts per billion
Entry point to the distribution system - from the Bull Run Watershed and Columbia South Shore Well Field	<0.05 parts per billion	0.028 parts per billion	0.048 parts per billion
Distribution System	<0.05 parts per billion	0.028 parts per billion	0.051 parts per billion

[1] During the year, two different method reporting limits (MRLs) were used to analyze chromium-6. The sample with results of <0.05 was analyzed with the test with the less sensitive MRL.



While there is not currently a standard for chromium-6, the very low levels detected in Portland's source waters do not represent an acute health risk based on the best available science. The risks discussed by the EPA are based on a lifetime exposure to chromium-6. EPA's final toxicological review of chromium-6 is expected to be completed in 2013. This risk assessment will form the basis of any federal regulations that may be developed. In addition, the EPA recently added total chromium and chromium-6 to the third Unregulated Contaminant Monitoring Rule (UCMR3) for an additional 12 months of monitoring between 2013 and 2015. PWB will continue to work closely with the EPA and with organizations such as the American Water Works Association to monitor this issue as developments emerge.

Groundwater Pump Station

GW Maintenance Operation

The Portland Water Bureau maintains two high-quality sources of water, the Bull Run watershed and the Columbia South Shore Well Field groundwater supply. The Bull Run, Portland's primary drinking water source, is an unfiltered surface water source. The Columbia South Shore Well Field provides Portland with a back-up drinking water source and is necessary for Portland to maintain its filtration exemption to the Bull Run supply. The ability to maintain its filtration exemption may require Portland to switch to groundwater quickly. The well field may also be used to augment the drinking water supply in summer and early fall when demand is projected to exceed the supply from the Bull Run watershed. Due to the complexity of the groundwater supply, it must be operated regularly to identify maintenance needs and ensure that it can be used on short notice. Each summer the Portland Water Bureau operates the well field for this purpose, operating each well for a short period of time and blending a small amount of groundwater with water from the Bull Run. The maintenance operation also allows the Portland Water Bureau to collect and analyze water quality samples to ensure that groundwater complies with all drinking water quality regulations. These results are included in this report. By performing a maintenance operation, the bureau ensures the reliability and water quality of the groundwater system when needed, either in an emergency or as part of seasonal supply.

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

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Portland Water Bureau
Commissioner Randy Leonard
Administrator David G. Shaff
1120 SW Fifth Avenue / Room 600
Portland, Oregon 97204

***************ECRWSS**
POSTAL CUSTOMER

Drinking water regulations require the city to mail this information to customers each year — it's the law.

Most of the language is also required – Congress and the EPA want to be sure that people know what is in their drinking water. The Portland Water Bureau agrees.

The Portland Water Bureau has tried to make this complex information readable and produce this report at a low cost. ***The Portland Water Bureau produced and mailed this report for 32 cents each.***

Bull Run River

PHOTO: ROMAN JOHNSTON

Printed on recycled paper
JUNE 2012

CONTACT INFORMATION

Portland Water Bureau
1120 SW Fifth Avenue/ Room 600
Portland, Oregon 97204
www.portlandoregon.gov/water
Public Water System #4100657

Portland Water Bureau
Customer Service: 503-823-7770

Portland Water Bureau
Water Line: 503-823-7525

FOR ADDITIONAL INFORMATION

Oregon Health Authority – Drinking Water Program:
971-673-0405
www.public.health.oregon.gov/HealthyEnvironments/DrinkingWater

The City of Portland will provide auxiliary aids/services to persons with disabilities. To request an ADA accommodation, please call 503-823-7404 or by TTY at 503-823-6868. Copies of this report are available on the Portland Water Bureau's website — www.portlandoregon.gov/water.

Spanish
Para obtener una copia de este reporte en español, por favor llame al **503-823-7770** o visite www.portlandoregon.gov/water

Russian
Чтобы получить копию этого отчета на русском языке, пожалуйста, позвоните **503-823-7770** или зайдите на сайт www.portlandoregon.gov/water

Vietnamese
Để được một bản báo cáo này bằng tieng Việt, xin gọi số **503-823-7770** hoặc đến mạng lưới www.portlandoregon.gov/water

Chinese
若想获得本报告的中文版本，请拨打**503-823-7770** 或访问: www.portlandoregon.gov/water

Moore-Love, Karla

From: Dr Dan <drdan42@gmail.com>
Sent: Thursday, April 23, 2015 1:34 PM
To: Council Clerk – Testimony
Subject: Testimony for Washington Park Demolition Hearing, April 23rd
Attachments: Wash Park City Council.docx

Please see attached testimony for the Washington Park Demolition Hearing

Regards,
Dan Berger

April 23rd, 2015

Dearest Mayor and City Commissioners,

My name is Daniel Berger, MD. I am a physician specializing in Emerngency Medicine, actively serving the greater Portland community.

Thank you so much for listening to public testimony on this important matter. The number of folks present at this meeting speaks volumes to not only the level of concern of We The People, but also to a degree of lack of trust in these proceedings.

As with Mt Tabor park, the public feels their involvement to discuss the needs or alternatives for these projects have been avoided, allowing us only to engage in "what goes on top" conversations. PWB administrators have publically stated "designing and building is glamorous, maintenance if boring." That may be well and true, but that is the responsibility that comes with being true stewards of our public resources. In the process, PWB is selling out the soul of the city with overblown projects that are not needed, putting us further into deep, deep debt spending money we desperately need elsewhere and don't have in the first place, as well as jeopardizing the health of our citizens and our children for generations to come.

It is worth pointing out once again that the rushed deadline to complete this project was fabricated by the city. In a letter to MTNA chair Stephanie Stewart from Eric Winiecki, Drinking Water Enforcement Coordinator of the EPA, he reiterated that there is NO federal deadline to disconnect the reservoirs. The only federal deadline was to submit "a plan" by April 1st, and that was complied with a long time ago, albeit without public input. The City can submit a new timeline to the OHA, containing a more responsible and community-approved mitigation plan.

And, like Mt Tabor Park, there are significant land ownership laws that are being brushed aside in the haste to get these corporate contracts underway. Both Mt Tabor and Washington Park consist of numerous different lots owned by either Portland Water Bureau

(Ratepayers) or Portland Parks and Recreation (Taxpayers). Both projects have PWB doing work and building infrastructure on land owned by PPR. Yet, no transfers of deeds, consolidations, easements, or anything has been obtained or recorded. If PWB ratepayers intend to build projects on land owned by city taxpayers, it needs to compensate the public. This has been repeatedly brought to the attention of all parties by PWB's engineering surveyors, and the city's own legal council, but these facts seem to be ignored. To proceed with either project would be, in a word, ILLEGAL. It would be like digging a well on your neighbor's property. Therefore, on this basis alone, this application should be outright denied until these land ownership and deed issues are resolved.

I implore you, as fellow citizens, to be our heroes – uphold your pledge towards good governance in representing will of the People, not our corporate contractors.

Thank you for your time and consideration in this very important matter.

Daniel R Berger, MD
6027 SE Main St

From: Winiecki.Eric@epamail.epa.gov
Sent: Thursday, March 19, 2009 8:41 AM
To: stewartstclair@gmail.com

Subject: Fw: LT2 Rule Non-Compliance Penalties

Ms. Stewart,
Public water systems subject to the LT2 Rule uncovered reservoir requirements must have an approved schedule in place by April 1, 2009 for complying with the Rule. For systems that are not in compliance with the requirement on April 1, EPA can issue an administrative order to noncompliers. If a water system violates an administrative order, EPA can assess penalties up to $37,500 per day of noncompliance. There is no specific deadline for installing reservoir covers... the requirement is to have an approved compliance schedule in place by April 1.
Eric Winiecki
Drinking Water Enforcement Coordinator
EPA Region 10

Moore-Love, Karla

From: Valerie hunter <v.hunter@comcast.net>
Sent: Thursday, April 23, 2015 4:35 PM
To: Council Clerk – Testimony
Subject: Oppose destruction of Washington Park reservoirs

To the Commissioners:

Please do not proceed with the planned demolition of the historic Washington Park reservoirs. There is no compelling reason to take this drastic step at this time. The LT2 will be revised next year. Normal public processes have been circumvented. Why are you rushing into this drastic, expensive, and irreversible destruction of a beautiful and historic public resource? Please stay the bulldozers! There is a better way to comply with LT2, if indeed the rule still stands after 2016, that leaves our heritage intact.
Thank you.

Valerie Hunter
1400 SE 60th Ave
Portland, OR 97215

Moore-Love, Karla

From: Seven Stevens <seven.root.stevens@gmail.com>
Sent: Thursday, April 23, 2015 12:47 PM
To: Council Clerk – Testimony
Subject: Washington Park Demolition

To Whom It May Concern,

I want it to be known that as a resident of Portland, OR I am officially opposed to any demolition at Washington Park.

Of course, if the will if the majority of our citizens fell in favor if such a demolition, I would acquiesce. However, due process is currently being disregarded in this matter, as our elected officials try to push through yet another huge project that ignores the will of the people.

Do not do this. Stand strongly against outside pressures and treat this issue with fairness and consideration towards your constituents.

My preference would be to wait until The EPA revises LT2 in 2016. Other communities have been allowed to forestall major changes until these revisions, and I believe Oregonians have the same right.

Thank you for your considerations.

Sincerely,

Seven Stevens

Sent from my iPhone

Moore-Love, Karla

From: Lawrence Hudetz <hudechrome@gmail.com>
Sent: Thursday, April 23, 2015 12:39 AM
To: Moore-Love, Karla
Subject: RoseMarie/For the record, Council Hearing on Washington Park Reservoirs April 23,2015
Attachments: Washington Pk Res004.jpg; LU 14 249689 submission for the record Historical Landmarks Commission.doc; April 23, 2015 Washington Park Reservoir Demolition council hearing.doc

Please enter the following for the record.
Two links and three attachments.
I plan to add oral testimony at the hearing.
Thank you.

RoseMarie Opp
1339 SE 130th Avenue
Portland, OR 97233
hudechrome@gmail.com

(Lawrence Hudetz name appears as we share email, his is hudechrome@usa.net)

http://bullrunwaiver.org

http://www.truth-out.org/news/item/28390-deep-questions-arise-over-portland-s-corporate-water-takeover

To: The Historical Landmarks Commission March 8, 2015
Re: LU 14-249659 DM
Washington Park Reservoirs Historic District

1. What part of "not understanding" the purpose of the fully functioning open reservoirs to our community public health do our city council and PWB not get or want to have on the table for discussion? When water is brought into our system from the Columbia S. Shore Well Fields the radon in that water can dissipate in the air with the fully functioning open reservoirs. Without the open reservoirs functioning as an integral part of the entire Bull Run Water System, that radon will be coming into our homes and workplaces with water usage. The lack of concern regarding this from our elected officials will allow radioactive water to be brought into our community. The history of water in Portland years ago, cholera became a problem in Portland from the Willamette River and the public needed a better water source. This then brought our community the Bull Run Water System and Open Reservoirs. We should not be going backward by eliminating those open reservoirs which then can bring about other problems of public health. Will our community years from now find noticeable lung problems as a result of radon?

2. The new tank up at Powell Butte has some vents but they are small and not effective as the open reservoirs. That tank also had 3000 cracks and over 200,000 gallons of water leaked for some time. Engineers in a KOIN article (those engineers not on the project and did not want to be named) said it could be a design flaw. In my view it would only be prudent to retain our open reservoirs.
http://KOIN.com/2014/02/26/powell-butte-reservoir-failing-leak-tests/

3. Washington Park, the Historical Olmsted Landscape Designs.
   Washington Park is considered by many to be the crown jewel of our parks.
   What will be left of that crown jewel other than remnants and photographs of what once existed in that park after the PWB project proposed up there?
   Some of us attended a committee meeting last November 2014 and what we heard was alarming.
   Project requirement: 30,000 trucks in construction going up the
   Burnside and Jefferson Streets and right through the Arlington neighborhood streets.
   Construction period of four years. The construction challenges:
   Public Safety
   Limited access to site for deliveries and materials removal
   Noise mitigation
   Worker parking
   Truck traffic and concrete/material deliveries
   My background is in design, and in my opinion, this PWB project is too large and out scale for this park landscape. The streets will be worn down with all these trucks and workings of the cement, dirt, noise? How is adequate mitigation possible for the neighborhood? What will happen to the character of our crown jewel of parks and that neighborhood? What will happen to the traditions of our Rose Festival, our Rose Garden and music events? All these will be out of reach for our community for four years?

4. This brings me to another critical point. Where has been the outreach and public notification for such a monumental project which will forever change this historic park?

http://www.arlingtonheightspdx.org/calendar/
This deadline for the official record and staff report and the tentative Historic Landmarks Commission tentative April 23rd meeting is not even on the Arlington Heights Neighborhood Association calendar.
http://www.portlandoregon.gov/oni/article/312804

In closing, I plead with the Historical Landmarks Commission to reject this application and if on appeal you review again the Mt. Tabor project to stand up for the two crown jewels of our city parks to save them from the city council and PWB directives and reject their applications.

Please understand that we are not mandated to do this now as the city tells us. Look only at the actions of NY to protect their open reservoirs and the lack of action our city has done in comparison. NY representative asked for a Waiver and NY received a reprieve until 2028. Our city council has not "seriously" worked for our community on this, they can say they have but evidence shows otherwise. The city set up it's own time frame on this. The EPA LT2 review is not complete until into 2016. It is only prudent to not proceed with any projects at this point. The city can ask for an extended period of time.
Our elected officials have not been good stewards of our city asset, the Bull Run Water System nor are they now good stewards of the health of our community.
For history information:
www.friendsofreservoirs.org/
Our public health is at stake with the removal of the fully functioning open reservoirs. It is unacceptable that our city refuses a discussion on this valid concern. Read about the public benefits of the open reservoirs;why radon coming from the well fields will bring radioactive water into our community.
www.bullrunwaiver.org/
The document we received at the November 2014 Committee meeting is called Washington Park Reservoir Improvements Project. That Sounding Board 9 meeting last November had very few people attending. I would like that document dated 10/29/2014 to be put in the official record.
Washington Park Reservoir Improvements Project
Sounding Board 9

The city has also not been good stewards of our community financial well being. It is unacceptable that the PWB brings up the concern of $1.5 million for upkeep on Mt. Tabor open reservoirs, but has the money to do all else such as $40 million at Mt. Tabor and the Washington Park project another $76 million. This weak response from PWB is an insult.

Please be the good stewards we need to assist in saving the crown jewels of our park system and in the process our open reservoirs which have historically provided our city with safe drinking water for over 100 years.

RoseMarie Opp
1339 SE 130th Avenue
Portland, OR 97233
503 253-5491
hudechrome@gmail.com

(Lawrence Hudetz name appears as we share emails)

To the City Council
For the record - LU 14-249689
Washington Park Reservoir Demolition - Hearing April 23, 2015

Portland's Historic Olmsted Landscape Design, pathway up to the Rose Garden to view Mt. Hood is a priceless heritage along with the open reservoirs fully functioning.
Those open reservoirs are now proposed to be demolished and replaced with a tank. Historic remants will be placed in amber and a walkway of posts of photographs depicting what once was were in design plans at a Committee Sounding Board 9 meeting. A new water pond of sorts is not the same as the function of the open reservoirs which were built as an integral part of our Bull Run Water System as providing our community with healthy drinking water.

In my view after the city and PWB are done with their proposal, the very heart of our city on both Mt. Tabor and Washington Park will have been taken, changed forever.
Not only the landscape changes but our water will be changed/degraded forever and why? So that our water bureau can spend millions more in contracts?

I have witnessed for years the city "piecemeal" taking away our Bull Run Water System.
I only hope that our city will not be able to again move forward to tell the public this application was approved by the Historic Landmarks Commission.

WATER - What got my attention at the hearing about the water is that the PWB said there was no use change. Obviously there is use change. Right now those open reservoirs are fulling functioning sending healthy water into our homes and workplaces. The huge change is that after a disconnect, we will no longer have the benefit of the fully functioning open reservoirs. We were told that any water left in "only aesthetic" reservoirs cannot now reach our homes, but will instead be drained into the sewer. Our pristine Bull Run water can not even accidentally be allowed to reach our taps. This is insanity. Closed storage tanks have throughout our country caused health problems discussed in EPA documents. Now we have the issue of radon that is in the water in the Columbia S. Shore well fields. The open reservoirs allow that radioactive water to dissipate in the air, the same cannot be done with closed storage tanks and it appears any vents in the tanks are small, not the same as the size of the open reservoirs function regarding the radon matter.
For the water bureau to characterize the project as no use change is insulting to those who know better. The application should be rejected on that usage change alone.

LANDSLIDE - Others are submitting the chart and documents that show in the early history there were landslides and construction as a factor. The city mitigated and did extensive work to where the annual rate of movement from 1987-2010 is 0.14 inch/year. My point is that the burden of proof here is on the applicant to prove there will not be any negative movement by their construction proposal to what has been stable for years. The applicant needs to prove why they promote this as a reason to do this project when the facts show otherwise that the mitigation done many years ago has worked.

GOAL 9: CITIZEN INVOLVEMENT

Findings: Policy 9.1
Citizen Involvement Coordination states: "Encourage citizen involvement in land use planning projects by actively coordinating the planning process with relevant community organizations, through the reasonable availability of planning reports to city residents and businesses, and notice of official public hearings to neighborhood associations, business groups, affected individuals and the general public."

In my opinion this Goal 9 has not been met. The general public would be city wide since this park belongs to the public and the water delivery system concerns mentioned are of city wide public interest. Meetings in Mt. Tabor and Arlington are not adequate for these major changes, our drinking water and parks. East Portland, North Portland, SW and all those who drink Bull Run Water are stakeholders and should have been notified and had meetings to discuss alternatives and that their drinking water and public health is at stake. The Federal Safe Drinking Water Act indicates that residents need to know of any change in their water.

33.445.010 - The Open Reservoirs as fully functioning are a significant part of the regions heritage. Replacing with a water pond is not the same, the heritage would be gone and with only pictures of the reservoirs left.
33.445.330 - My response is there has not been an opportunity for the community to fully consider alternatives to destruction.

Many of the Codes and Goals where the the applicant states the goal has been met are words the applicant of course chooses to make their case. The reality of whether they hold is another matter, such as in:

GOAL 6 TRANSPORTATION
Again the applicant is choosing to focus language to walk and bike, etc. as a positive, this is the case now. The applicant is ignoring the mention of the construction requirements of 30,000 truckloads on Burnside/Jefferson Streets right through the Arlington NH streets. Words are one thing, reality on the ground quite another, such as public safety, and gridlock.

The following Bureaus have responded with no issues or concerns:
- Water Bureau
- Life Safety Division of the Bureau of Development Services
- Bureau of Environmental Services
- Fire Bureau
- Bureau of Transportation Engineering
- Site Development Section of BDS

I find it troubling that all these bureaus have no issues or concerns.
Gridlock in traffic certainly would be a problem to reach a fire in a timely manner.
Costs of fixing the streets after the many truckloads I would think would be of concern to the Transportaion Bureau.

EX PARTE CONTACT - The applicant is the Portland Water Bureau. They have had no communication with the council? Any ex parte contact must be disclosed.

CONFLICT OF INTEREST - The Mayor has a long history working for HDR, they have a large Water Division and in my opinion the Mayor has a conflict of interest and ought to recuse himself from water decisions and/or those that bring HDR into city projects.

The process of this case seems quite fragmented.
There are other citizens who will be submitting testimony about this and about documents they had requested were not forthcoming in a timely mater or at all for this case.
Staff response that traffic, etc. other matters would be brought up in a Type III later illustrates that fragmentation. In my view the entire picture ought to be brought up in order to see whether any demolition work in that park is even feasible.

Would we in a Type III be looking at all the other concerns, problems, but told then that the city council approved the demolition?

I don't see how living in a neighborhood with the noise, traffic, and all else during this proposed demolition for four years of construction, 30,000 truckloads is even remotely reasonable. I don't live there but it is a nice park to retreat to the Historic Olmsted Landscape, the Rose Garden and events, the Arlington neighborhood homes of character, all will be in chaos and I don't believe mitigation to combat problems with this out of scale project for the area is really possible.

Concerning our public health I don't believe that there is adequate mitigation in degrading our water and bringing in radioactive water into our homes and workplaces when we use the well fields. Radon can dissipate in the air with fully functioning open reservoirs therefore our open reservoirs should be retained as a vital componant in our water delivery system that provides our community drinking water.
The EPA LT2 was based on cyrptosporidium which we don't have as this was from a sewage problem and we don't have the problem because our watershed is in federally protected land. Our city council must ask for a Waiver to retain our open reservoirs.
So we have an example here of we don't have a problem but where demolishing the open reservoirs will most likely create new problems.
For Open Reservoirs Health Benefits
and the The Public Health Risk of Radon
For this and more information:
http://bullrunwaiver.org/

The following from Friends of Safe Drinking Water ad in Northwest Examiner, May 2011:
Open reservoir public health benefits

- Carcinogenic gases such as Radon and chloroform vent safely into atmosphere
- No deaths form mocroorganisms or chemicals
- Oxygenation provides natural disinfection process

and cleaner, fresher tasting drinking water

- Sunlight inhibits nitriication and toxins
- Future costs - minimal for maintenance

Public health problems with covered storage tanks

- Carcinogenic gases unable to vent end up in homes, schools, and workplaces
- Deaths from Salmonella, unvented toxic gases
- Rubberized asphalt coatings contain carcinogens from petrochemicals that

may leach into water

- Covering encourages nitrification and toxins
- Future costs - $800 million with debt

I oppose the demolition of the open reservoirs.
New York and NJ have worked for their community to retain their open reservoirs. Senator Schumer communicated to EPA that the LT2 was too great a financial burden for their community. NY received a reprieve until 2028. The EPA LT2 rule is being reviewed now into 2016. Our council set their own time frame and could ask for more time and a Waiver. The evidence is clear, our council decided not to. Senator Merkly told me that he could not do more as this council has not asked him. The cost of the Washington Park Reservoir Demolition is $76 million. It would only be prudent to put a moratorium on all LT2 projects and to ask for a Waiver. I emphasize to "seriously" ask for a Waiver from the EPA LT2. Commissioner Fritz has indicated she must comply with the federal rule. Where then do Senator Shumer and those in NJ stand? They are asking for relief. The federal rule is being

reviewed, until that happens why would this be a violation of the rule by asking? What about the oath our council takes, are they not to be good stewards of our valuable city asset, our Bull Run Water System? Unfortunately our council has also gone along with the deferred maintenance which is one more abuse of that system and detrimental to our public health.

RoseMarie Opp
1339 SE 130th Avenue
Portland, OR 97233

hudechrome@gmail.com
(Lawrence Hudets name appears as we share emails, his is hudechrome@usa.net)

Moore-Love, Karla

From: floy jones <floy21@msn.com>
Sent: Thursday, April 23, 2015 10:06 AM
To: Council Clerk – Testimony
Cc: Hales, Mayor; Shibley, Gail; Commissioner Fish; Schmanski, Sonia; Saltzman, Dan; Grumm, Matt; Finn, Brendan; Fritz, Amanda; Howard, Patti; Bizeau, Tom; Steve Novick; Warner, Chris
Subject: Washington Park Reservoir Demolition Review LU
Attachments: Demolition Washington Park ResLUreview.pdf

Attached for the record of City Council's Washington Park Reservoir Demolition Land Use Review, April 23, 2015 are comments from Floy Jones on behalf of Friends of the Reservoirs. Supporting documents have been sent mostly separately via e-mail.

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2204 SE 59th Ave.,
Portland, Oregon 97215

To: Portland City Council
Re: Washington Park Reservoir Demolition LUR Review, April 23, 2015
Submitted by Floy Jones on behalf of Friends of the Reservoirs
2204 SE 59th Ave., Portland, OR 97215

Numerous supporting documents referenced in these comments have been submitted via separate e-mails.

The Friends of the Reservoirs strongly opposes the proposal to demolish Reservoir 3 and Reservoir 4 and the Weir buildings at Washington Park. Demolition is not required by the onerous EPA LT2 regulation nor is it necessary for any other reason. The Water Bureau's Demolition Land Use Review process has not met code regulations including the intended purpose to "ensure that there is opportunity for the community to fully consider alternatives to demolition". The Water Bureau has intentionally defied City Council Resolution 36237 that requires bringing stakeholders together to determine what action to take if a "risk mitigation" reservoir option is not available. Contrary to the Bureau of Development Service's (BDS) staff report, Land Use criteria is not met by this demolition plan. The **Portland Water Bureau's Cascade Design Professionals, Robert Dortignacq, 2010 Historic Structures Report**, which reaffirms that the reservoir structures are for the most part in good condition, was withheld from the Historic Landmark Commission. Landslide and earthquake concerns are overstated. Eliminating Portland's recently upgraded and well-functioning historic open reservoirs will create new and unique cancer-causing public health risks.

> **33.445.330 Demolition of Historic Resources in a Historic District**
> Historic Landmarks in a Historic District are subject to the regulations of Section 33.445.150. Demolition of other historic resources within a Historic District requires demolition review to ensure their historic value is considered. The review period also ensures that there is an opportunity for the community to fully consider alternatives to demolition.

Documentation of reservoir infrastructure and other upgrades including the 2006 Council Resolution and press release submitted via separate e-mail communication. Ratepayers are presently financing the Washington Park reservoir upgrades (that included 2006 opening up of the reservoir sites to the public) completed between 2003 and 2010 (Black & Veatch contract #36297, Natt McDougal # 334785, HDR, and others) – with debt costs increasing over time - The Water Bureau long ago abandoned the better practice of pay-as-you go outlined for Mayor Katz in the Water Bureau's October 3, 2003 reservoir project letter.

EPA LT2 COMPLIANCE

There has been no meaningful public involvement process. The IRP Reservoir Resolution 36237 requires utilizing the city's adopted Principles of Good Public Involvement when taking action related to the open reservoirs- full consideration of alternatives to demolition which include installation of covers, UV "treatment at the outlet", disconnection and building storage elsewhere, and **the community supported option of reapplying for an Oregon Health Authority deferral while working with other communities to reinstate the "risk mitigation" option inexplicably removed from the final LT2 rule.**

The Portland Water Bureau can continue to use both of Washington Parks open reservoirs, Reservoirs 3 and 4, as part of the drinking water system and be in compliance with federal regulations if Portland installs reservoir covers on the already installed grill work.

Prior to construction of the new $120 million Powell Butte II underground tank, Portland had an excess of in-town storage at Mt. Tabor and Washington Park as reported by the PWB to the Oregon Health Authority and the EPA - 50 million gallons of excessive storage - thus the Water Bureau has not been utilizing all of the storage at Washington Park (or at Mt. Tabor) while not being honest with the public about this fact. The issue of unneeded storage was discussed at the March 30, 2015 Historic Landmark Commission meeting where the lead engineer Teresa Elliot confirmed that there would be no storage at Washington Park for fours years as the Water Bureau intends to demolish both of the reservoirs simultaneously. The follow-up question from a

Commisioner, "Why don't you build the storage that is clearly unneeded elsewhere?" The Water Bureau refused to answer, having already avoided affording the community it's right to fully consider alternatives, the Water Bureau refused to answer. Video and audo links provided separately.

RESERVOIR COVERS

In 2002/03 the Water Bureau, absent any public process or regulatory requirement, installed grill work for floating reservoir covers at the Washington Park reservoirs. The Water Bureau also installed a white liner on the upper Washington Park reservoir, which was intended to last 25 years as represented by an onsite PWB engineer at the time. In a February 19, 2003 Power Point to City Council referring to the "Washington Park Solution" of covers, the Water Bureau said that this "eliminated regulatory modification" and that the "historic structures are not affected" , "trees remain in place", and "roads remain open."The cover material (hypalon) intended to attach to the installed grill work was purchased by the Portland Water Bureau but never installed. When the 2004 *Independent Reservoir Panel* did not support "treating or covering" Portland's open reservoirs (the PWB's arguments failed to hold water) and City Council ordered the Water Bureau to terminate covering the Washington Park reservoirs, the Water Bureau attempted to sell the hypalon reservoir covers on eBay. According to the Oregonian's September 21, 2004 article the cost of the covers and hardware was $398,000. " However, at the close of bidding on eBay Thursday, the highest offer for the whole package was a mere $18,000 to an anonymous bidder." It was subsequently revealed that Water Bureau employees were the anonymous bidders. http://www.wwdmag.com/portlands-water-bureau-lists-reservoir-covers-ebay-bids-itself-then-balks

Commissioner Saltzman stopped the sale but the final disposition of those covers has remained hidden. The cover grill work has remained in place at the Washington Park Reservoirs 3 and 4. The estimated cost of replacement of the floating covers would be somewhere in the vicinity of $1 million compared to the Water Bureau's plan for demolition and replacement that could reach $100 million (current estimate $80 million).

While covering the reservoirs was absolutely not supported years ago for many reasons including the fact that a "risk mitigation" option was included in the draft 2003 LT2 regulation, it is still not ideal. This option does meet regulatory requirements and would provide opportunity for the Congressional delegation to work in support of revising the poorly crafted LT2 rule such that "risk mitigation" is again a compliance option. In that the Water Bureau's self-imposed compliance deadline for Washington Park is 2020, the covers might never need be installed if the "risk mitigation" option is restored as has been requested by New York's water department, Rochester's water department and others. Oregon's Congressional delegation members have indicated that they would join forces with Senator Schumer and others to support rule revision if demolition/disconnection projects were placed on hold.

Or

"TREATMENT AT THE OUTLET"

The community has never had opportunity to fully consider the EPA LT2 "treatment at the outlet" compliance option. In 2004 the PWB made no argument to City Council that "treatment at the outlet" would be costly or otherwise difficult to install. Their February 19, 2004 PowerPoint to City Council presented at a Council hearing included "treatment at the outlet" as a viable option. MWH's Reservoir Study Contract 30491, a contract that was amended and extended nine times indicated that **"treatment at the outlet" was a viable option. Montgomery, Watson Harza Open Reservoir Study Tech Memorandum 2.7-Water Quality Evaluation, November 2001.**

Since then the costs of UV "treatment at the outlet" have dramatically declined. **Rochester** New York has two historic open reservoirs set in city parks. Rochester initially planned on building underground storage after learning of the EPA LT2 rule but in response to **strong community opposition** they investigated installing UV radiation bulbs and found that costs had dramatically dropped. Responsive to Senator Chuck Schumer's success in including revision of the EPA LT2 regulation as part of Obama's order to revise "onerous "regulations, Rochester sought and secured a 10-year deferral of reservoir projects until 2022. Rochester's deferral was supported by their Mayor and the Governor of New York supports rule revision.

Rochester is concurrently working in support of revising the EPA rule to avoid wasting money on "treatment at the outlet", a project that will will provide no measurable public health benefit. In

recent years the Portland Water Burea has said that they have only done a "back of the napkin" look at treatment at the outlet (documents supplied by the PWB confirm the lack of a comprehensive, independent examination of this option), thus this alternative to demolition has never been fully considered by the community.

Or

BUILDING STORAGE ELSEWHERE

The Water Bureau has not produced a recent alternative site analysis having submitted to BDS an out-of-date 13-year old analysis conducted by Joe Glicker and others with MWH Global. On March 30, 2015 a Historic Landmark Commissioner asked the obvious question of the Portland Water Bureau engineer Teresa Elliott, why would you demolish significant historic resources when it is clear that storage is not needed and digging will destabilize the land. The Water Bureau confirmed that the plan involved eliminating all storage at Washington Park for four years, but refused to respond to the inquiry regarding alternative siting of the unneeded storage.

While the 100-year 1996 flood did not destabilize the historical landslide that has been stable for years, onsite digging will cause problems. Links to both audio and video documentation of Water Bureau statements at the HLC meeting has been submitted for the record separately.

NO SCIENTIFIC BASIS FOR "TREATING OR COVERING"

Just as with demolition there is no scientific or on balance any reason for employing any LT2 compliance option beyond the lowest cost option. Scientific sampling of 7,000 liters from the open reservoir outlets as part of the American Water Works Association Research Foundation # 3021 study confirms, as did Portland's costly, intensive Bull Run EPA LT2 variance application study, the 100% absence of infectious *Cryptosporidium* in Portland's drinking water. Bacteria found in both covered and open reservoirs is treated with chlorine. Portland's bacteria detections are documented in the Oregon Health Authority online water system data **(copy of the recent 36 positives at the covered Nevada tank submitted via separate e-mail)** . Subsequent to the 36 covered tank positives and the Water Bureau's failure to resolve the problem the Water Bureau simply stopped sampling at this site accepting the violation but leaving the public at risk. The public is unable to determine at the OHA site where the Water Bureau is not sampling.

Buried tanks do not prevent contamination as is evident by the break-in and contamination of a WB buried tank – Tabors buried Reservoir 7, where a bottle of Hydrochloric acid and other debris was tossed in after the breach. The public was not notified until limited exposure of the incident by watchdogs. Documentation submitted separately via e-mail.

By all accounts there will be no measurable public health benefit from either "treating or covering" open reservoirs. All EPA documented distribution storage tank public health problems have been with covered storage.

The compliance option with the broadest public support is to secure a deferral of reservoir projects while concurrently working in conjunction with Oregon's Congessional delegation, Senator Schumer and others to ensure reinstatement of the EPA LT2 "risk mitigation" compliance option.

SECURE A DEFERRAL

Friends of the Reservoirs has requested that our new Governor Kate Brown, head of the Oregon Health Authority (OHA), direct that bureau to approve a deferral of projects. If the Portland Water Bureau worked in support of, rather than against community interests, a deferral of projects minimally in line with Rochester's deferral could be approved by OHA. Previously, the Water Bureau failed to submit adequate supportive documentation to back up a deferral request, used a surrogate to send OHA a message that they wanted to pursue burial projects, and the City failed

to lobby OHA to support the deferral request.

LANDSLIDE & EARTHQUAKE RISK OVERSTATED

The community has had no opportunity to comprehensively examine the Water Bureau"s overstated claim with regard to landslide risk. After a public presentation on Mt. Tabor geology in 2012, I spoke with a PSU geologist (and Water Bureau consultant) regarding the plans for the Washington Park reservoirs. He advised that as long as there was no digging at Washington Park there should be no serious threat of landslides based on historical study. PSU landslide analysis confirms little recent movement. **See graph showing dimished slippage, submitted separately.** Note that this information was withheld from BDS and the HLC. At the end of the 2004 *Independent Reservoir Panel* process the Water Bureau knew that they had failed to convince the Panel majority (a panel that excluded every single NA in the city and every single neighborhood coalition) to support their demolition/disconnection plans. In the final week of the long-running panel process an anonymous phone call was made (by a woman subsequently chastized publicly by Mayor Katz) to the Urban League panel member suggesting that the reservoirs were an earthquake threat. Friends of the Reservoirs spent hundreds of hours the following week researching Water Bureau consultant documents, PSU geology maps, Water Bureau documents, geological records and other information that showed that a serious earthquake was expected to cause only minor leaking at the reservoirs. Many of these documents have since been shared with Commissioner Amanda Fritz.
Research confirmed that the Water Bureau's backup source,the Columbia South Shore Well Field would likely be lost or severely damaged due to having been sited in a high liquefaction zone.

The Water Bureau has a well-documented history of overstating risks when intent on pushing costly and often controversial build projects over "boring" maintenance that protects assets and keeps rates low. The Federal Energy Regulatory System that regulated the small hydro plant located at the Mt. Tabor reservoirs (unware for several years that the Water Bureau had taken Reservoir 6 offline since 2010 without notifying them) called out the PWB for overestimating inundation in the event of a catastrophic dam break event (**FERC letter documenting such submitted separately**). The Washington Park reservoirs like the Mt. Tabor reservoirs are very well built as documented in many Water Bureau documents including the 2010 Dortinacq Historic Structures Report thus are unlikely to completely fail even in a strong seismic event. And given the small size of the Washington Park reservoirs the inundation area would be small.

The Water Bureau advised the Historic Landmark Commision on March 30, 2015 that onsite digging could trigger a landslide.

System-wide leaking including the Washington Park reservoirs is limited as has been repeatedly reported by the PWB to their budget committee including when I was a member of that committee. The Washington Park reservoirs have not been leaking anywhere close to the leaking at the newly constructed costly $121 million Powell Butte II tank, which was leaking as a result of massive number (3200) of cracks as reported by KOIN 6 TV investigators in 2014. KOIN's report came after their hard-fought public records requests subsequent to backroom industry discussion of the serious problem with the new tank, http://koin.com/2014/05/20/powell-butte-ii-reservoir-design-contract-balloons/
. The new $121 million Powell Butte II underground tank project was leaking enough to fill an Olympic sized pool every day.
Note that the cozy CH2MHill design contract for that project when last checked was 45% over budget.

The Powell Butte tank Land Use decision acknowledged concerns with flooding of homes associated with a 50 million gallon underground tank, confirming that flooding risk is not eliminated with new *seismically* upgraded underground tank when compared with the subtantively built open reservoirs.

The Portland Water Bureau has not met the requirements for compliance with Chapters 33.445 and 33.846

The Portland Water Bureau has **not** demonstrated that they considered the historic value of Portland's open reservoir resources when making their backroom and unsupported decision to demolish the Washington Park open reservoirs. As stated above the community was never

afforded the opportunity to fully consider the alternatives to demolition. The Water Bureau's selected so called "Sounding Board" does not represent broad-based community stakeholders, and does not fit the intent of City Council Reservoir Resolution 36237. **The PWB's "Sounding Board" was not established to "allow the community to fully consider alternatives to demolition", but for the Water Bureau and their army of consultants to focus the conversation about what happens after the demolition.** In 2002 the "What goes on top" process was exponentially lengthier with greater community involvement, but of a similar nature wherein the consultant Joe Glicker (then with MWH Global, now with CH2MHill) told the community the only thing they could talk about is what happens after the degradation of the open reservoir system. The "What goes on Top" committee ultimately challenged the Water Bureau's limiting of the scope of the community discussion.

Only a handful of people were aware of the Water Bureau's "Sounding Board" meetings. Private meetings with selected individuals is not a meaningful public process for meeting the City's adopted Principles of Good Public Involvement.

The Portland Water Bureau and their cozy revolving-door consultants have been trying for decades to force "fun" (as described in 2013 by Water Bureau engineer Stan Vanderberg at a wholesale customer water managers meeting) tank burial projects. In 2004 Water Bureau Administrator Mort Anoushirivani when asked at a public infrastructure meeting why the Water Bureau was spending so much money on revolving-door consultant studies while deferred maintenance (as referenced by a 2004 City Auditor report) was avoided, responded by saying "designing and building is glamorous and maintenance is boring."

The 2002 MWH Global/ PWB Reservoir burial Permitting Strategy document delineates tactics and strategies for thwarting community opposition to burying the reservoirs via manipulation of Land Use laws. **Document submitted separately via e-mail.**

When trying to force unsupported reservoir demolition and covering projects between 2001 and 2004, PWB PR staff including Tim Hall repeatedly told the public that the reservoirs were not historic resources. It was not the Water Bureau that worked to place the reservoirs on the National Register of Historic Places in 2004 but several members of the Friends of the Reservoirs that dedicated the better part of a year toward the effort. Friends of the Reservoirs is a Water Bureau watchdog organization with members representing both sides of the river that formed in response to 2001 line-item budget decisions to cover Washington Park reservoirs and demolish the Mt. Tabor reservoirs.

At a budget presentation in March 2015 the Portland Water Bureau failed to include the historic open reservoirs as Water Bureau assets, let alone as the significant water system assets they have been and remain today. Chet Orloff suggested in his June 2006 letter to Council supporting reservoir upgrades and opening up the reservoirs to the public (better alternative to demolition) that the Water Bureau install permanent exhibit boards that would "thoroughly inform citizens of, and deepen pride in these great assets", wrongly believing that the Water Bureau had abandoned "still born" plans to demolish. I was present at this Council hearing. **Orloff's letter, the 2006 Council Resolution and associated press release were submitted for the record in a separate e-mail.**

The Portland Water Bureau was the only utility in the entire nation that was secretly seated at the table serving on the EPA LT2 Federal Advisory Committee. They brought with them a revolving-door consultant, Joe Glicker, a former PWB engineer, whose associated global engineering firms have profited from the onerous one-size-fits-all regulation that by all accounts will provide no measurable public health benefit to systems like Portland's Bull Run open reservoir water system. A list of some of the contracts awarded to Glicker's associated corporations was provided to the HLC in the Mt. Tabor Disconnect LU case and has been provided City Council in the past.
It was the Water Bureau in isolation and/or in backroom consultation with consultants who set the fast-track schedule for reservoir compliance. There is no deadline in the LT2 rule for reservoir compliance (**See e-mail from EPA Region 10 representative copied below**)

Demolition Criteria: Demolition of the resource has been evaluated against and, on balance, has been found supportive of the goals and policies of the Comprehensive Plan, and any relevant area plans

DEMOLITION DOES NOT MEET COMPREHENSIVE PLAN GOALS

GOAL 1: This goal is best met by installing "covers" or "treating at the outlet" or by an Oregon Health Authority deferral, an EPA waiver or a variance which is allowed by the Safe Drinking Water Act for "treatment techniques" such as the "treat or cover" EPA LT2 requirement- See additional comments above.
Goal not met by demolition
GOAL 2: The land around the reservoirs was opened up to the public in 2006 during daylight hours after extensive upgrades were completed including upgrading and reopening the grand entry staircase. Friends of the Reservoirs participated in the subsequent celebration which took place on the day Randy Leonard announced that his staffer David Shaff would be permanently appointed as Water Bureau director. **2006 Council Resolution, press release and other documentation provided separately.**

The value to the community will be significantly diminished not improved by demolition of the open reservoirs.
Goal not met by demolition
GOAL 3 NEIGHBORHOOD: The PWB specifically avoided opportunity for the public to fully consider options to avoid demolition. **See comments above and documentation provided separately.** It was public opposition to the lack of public process in 2001 that lead to the 2004 *"Independent Reservoir Panel"* which after opportunity to consider all of the options (with much of the significant information provided the panel by the Friends of the Reservoirs), they could not support the Water Bureau's proposed demolition of the Tabor reservoirs and covering Washington Park reservoirs.

Additionally, the WB failed to notify stakeholders of meetings associated with this Washington Park reservoir demolition case, including conferences with the Historic Landmark Commission. In order to make significant participation including research difficult they brought this Demolition LU case forward over the Christmas holiday overlapping the Mt. Tabor LU process. See information above and below.
The Water Bureau failed to provide the Historic Landmark Commission the 2010 70-page Historic Structure Report that documents, as does the referenced MWH nine -year study report, that the reservoirs are in relatively good condition. See documentation and comments above and sent separately.
The Washington Park Reservoirs are significant, unique and irreplaceable community assets.

Goal not meet by demolition.
GOAL 6 TRANSPORTATION: The promenade around the reservoirs was opened up following costly upgrades in 2006 including the upgrade construction of the grand entry staircase, new wrought iron fencing, etc.. **See comments above and documentation 2006 Council Resolution, press release, Chet Orloff letter submitted separately.The significant value of the historic open** reservoirs by far supersedes the minimal night entry restrictions. Goal not met.

GOAL 8 ENVIRONMENT: The onerous EPA LT2 regulation is under review and revision. Landslide risk is overstated. See comments above and documentation submitted separately.
Goal not met by demolition

GOAL 9: CITIZEN INVOLVEMENT **– PUBLIC INVOLVEMENT AVOIDED; COUNCIL ORDINANCE REQUIRING PUBLIC INVOLVEMENT DEFIED** There has been no citizen involvement in the decision-making process as required by the Independent Reservoir Review Panel **Ordinance # 36237** (attached for the record). A meaningful public process would have thoughtfully and publicly considered all EPA compliance options with all community stakeholders seated at the table. All stakeholders would have equal access to all pertinent information without having to deal with the Water Bureau's stonewalling public records requests or having to go to other utilities for factual information as has been the case over and over for decades. The Portland Water Bureau made all significant land use decisions backroom in **defiance of the reservoir City Council Ordinance # 36267** which required bringing community stakeholders together to determine what

action to take if the LT2 "risk mitigation" option could not be met. Friends of the Reservoirs was present when this ordinance was negotiated with Commissioner Saltzman in 2004. Mayor Potter was very supportive, insisting on inclusion of all community stakeholders in ANY future decisions/actions impacting the open reservoirs.

The relevant sections of the ordinance include but are not limited to: "BE IT FURTHER RESOLVED, that the City Council directs the Water Bureau to work with Portland Parks and Recreation, the Police Bureau and members of the public representing commercial and residential ratepayers, neighbors and stakeholders, to develop and submit to the appropriate state or federal regulator agency a risk mitigation proposal for the City's open finished drinking water reservoirs after the LT2ESWTR is promulgated in final form using a process consistent with the City's adopted Principles of Good Public Involvement"; and BE IT FURTHER RESOLVED .....utilizing meaningful public process consistent with the City's adopted Principles of Good Public Involvement, in future actions related to the open reservoirs. Inexplicably the EPA removed the "risk mitigation" option that was included in the draft 2003 regulation from the onerous and scientifically unsupported final LT2 rule released in 2006. Community stakeholders (including Friends of the Reservoirs) should have been brought together prior to the Portland Water Bureau's development of any reservoir compliance plan.

Friend of the Reservoirs has devoted tens of thousands of volunteer hours over the last 12 plus years working to protect the significant and well-functioning resources that are Portland's historic open reservoirs. We have worked with a broad base of community stakeholders including many neighborhood associations, neighborhood coalitions, public health organizations, businesses and business coalitions, environmental and social justice organizations - all of whom have written to City Council and/or the Congressional delegation in support of alternatives to the current reservoir plan. Over 30 community organizations have opposed the Water Bureau's burial and covering plans since 2002. At least 22 of these organizations have written to City Council, the Congressional delegation and/or testified in support of alternatives since 2010.

Forty (40) members of the public attended the Water Bureau's first public meeting (2014) related to the Washington Park demolition plans. No information was presented on any of the viable options that would avoid demolition. Overwhelmingly, everyone in attendance at this meeting save one opposed the Water Bureau's demolition plans. By design the Water Bureau has avoided providing opportunity for the community to fully consider alternatives to demolition. Just as in 2002 the Water Bureau wants to limit ratepayer discussion to what happens after the degradation of Portland's significant water system and community assets.
All other meetings were poorly attended as the community was not informed. See comments above.
Goal not met

GOAL 11 PUBLIC UTILITIES
Goal not met- See comments above addressing grill work and Water Bureau plan to go four years without any storage at Washington Park.
BDS and the Portland Water Bureau again incorrectly reports,
In addition, staff notes that the reservoirs are currently restricted from public access due to liability concerns. Significant ratepayer dollars were invested in opening up the Washington Park reservoirs to the public and upgrading the infrastructure (Mt. Tabor reservoirs have always been open to the public). **June 2006 Council Resolution, press release and letter from Historian Chet Orloff supporting the opening up of the reservoir sites to the public and budgeting for infrastructure upgrades submitted separately for the record.** This ocurred after the finalization of the LT2 regulation.

GOAL URBAN DESIGN
Enhance Portland as a livable city, attractive in its setting and dynamic in its urban character by preserving its history and building a substantial legacy of quality private developments and public improvements for future generations
By demolishing Reservoirs 3 and 4 and the Weir building that have served the city for more than 100 years and have been upgraded to provide safe water for another 50 years, the city is failing to preserve Portland's heritage, beauty, civic identity and its economic vitality is greatly diminished.

BDS staff report is incorrect. *Unfortunately, the overwhelming forces of nature have not been kind to these structures and the preservation of these facilities has been an ongoing challenge since*

before their initial completion. It is not nature that has been unkind but the Portland Water Bureau's focus on revolving-door consultant contracts and "fun" and "glamorous" build projects over deferred maintenance that have lead to deterioration. However, the **70-page 2010 Cascade Design Robert Dortignacq Washington Park Historic Structures Report** which the Water Bureau withheld from the HLC and BDS and City Council tells a different story. The Historic Structure report says that for the most part the reservoirs are in good condition which confirms the report from a 9-year MWH Global study of the reservoirs which is referenced in the Dortignacq report.
BDS also incorrectly reports the *continued preservation of the existing historic reservoirs, with the persistent landslide pressures continuing to compromise their structural stability, appears to be unsustainable in the long run.* ***See Table C-1 Open Reservoir Facilities at Mt. Tabor and Washington park Schedule of Proposed Capital Facility Projects by Year*** **which lists project to be completed over a 20 year period to keep the reservoirs safely operating for 50 years. Landslide stability is not noted as an issue in this document resulting from a nine-year study of the reservoirs.** It is unsustainable and bad governance to waste the significant and costly ratepayer investments made over the last 10 years, continually raising water rates and base charges, making Portland unaffordable for the middle class. **See Steve Novick's 2013 deferral request to the Oregon Health Authority submitted separately addressing the skyrocketing of rates.**

The goals of the Comprehensive Plan are not supported by this plan- see additional comments above.

Economic, Sustainability, Urban Design, Public Involvement, Neighborhood, Transportation and Public Health, Utility goals are not met with this demolition plan.

Significant investments in upgrades were made at the Washington Park reservoirs between 2003 and 2010. The significant costs associated with these consultant, design and construction contracts will be borne by the ratepayer over a 25 year period with those costs increasing over time. Many of the upgrades were designed to keep the reservoirs safely operating for 50 additional years. The majority middle class ratepayers cannot afford any further rate increases on top of rate increases that have been staggeringly high since 2004. The Water Bureau plans another 7% increase in water rates to be approved by Council May 2015.

The open reservoirs avoid new and unique public health risks associated with burying Portland's open reservoirs, for example cancer-causing Nitrification, a problem EPA has long scientifically documented with buried storage. EPA acknowledged in their Coliform Rule papers that they failed to address the Nitrification problem when promulgating the LT2 regulation. Radon, from Portland's secondary lower quality source, the Columbia South Shore Well Field, which presently vents through the open reservoirs, will not be able to vent adequately with the elimination of open reservoirs. Radon entering homes via water will permeate homes every time water is used for any purpose. Radon is the second leading cause of lung cancer in the United States.

The historic character of these resources cannot be replaced. The water system, the park, the surrounding neighborhoods and the City will be significantly harmed. On June 21, 2006 Historian, Park Board Member, the former chair of the Tabor "What goes on Top" committee, Chet Orloff ,wrote to Portland City Council praising them for reconsidering their earlier decisions on the open reservoirs. He additionally suggested "greater historical interpretation of the reservoirs with some permanent, on-site exhibit boards mounted adjacent to them, presenting information and images about the history of the reservoirs, the story of our great water system... to "more thoroughly inform citizens and deepen everyone's pride in, these great assets." The Water Bureau ignored Chet Orloff's suggestions, not wanting to promote the historic resources as the significant assets to our water system and city as they have been for over 100 years.

DENY THE PERMIT
City Council must protect Portland's open reservoir water system, Portland's water system pride and heritage and ratepayer's investment, and thus must deny this abominable demolition plan.

MITIGATION: Approval of any alteration to the open reservoirs, including the unconsidered options of installation of the floating covers to the grillwork or installation of UV radiation bulbs, disconnection should include a mitigation plan that requires completion within the next 3 years of

the short-term maintenance projects outlined in the **2010 Robert Dortignacq Washington Park Historic Structures Report** submitted for the record via separate electronic communication. All restoration and maintenance projects recommended in this Historic Structures Report should be mandated by City Council to be completed over a reasonable timeframe to support preservation.

Addendum

1.Documentation that there is no deadline in the LT2 rule for reservoir "treat or cover" compliance
From: Winiecki.Eric@epamail.epa.gov

Sent: Thursday, March 19, 2009 8:41 AM

To: stewartstclair@gmail.com

Subject: Fw: LT2 Rule Non-Compliance Penalties

Ms. Stewart,

Public water systems subject to the LT2 Rule uncovered reservoir requirements must have an approved schedule in place by April 1, 2009 for complying with the Rule. For systems that are not in compliance with the requirement on April 1, EPA can issue an administrative order to noncompliers. If a water system violates an administrative order, EPA can assess penalties up to $37,500 per day of noncompliance. There is no specific deadline for installing reservoir covers... the requirement is to have an approved compliance schedule in place by April 1.

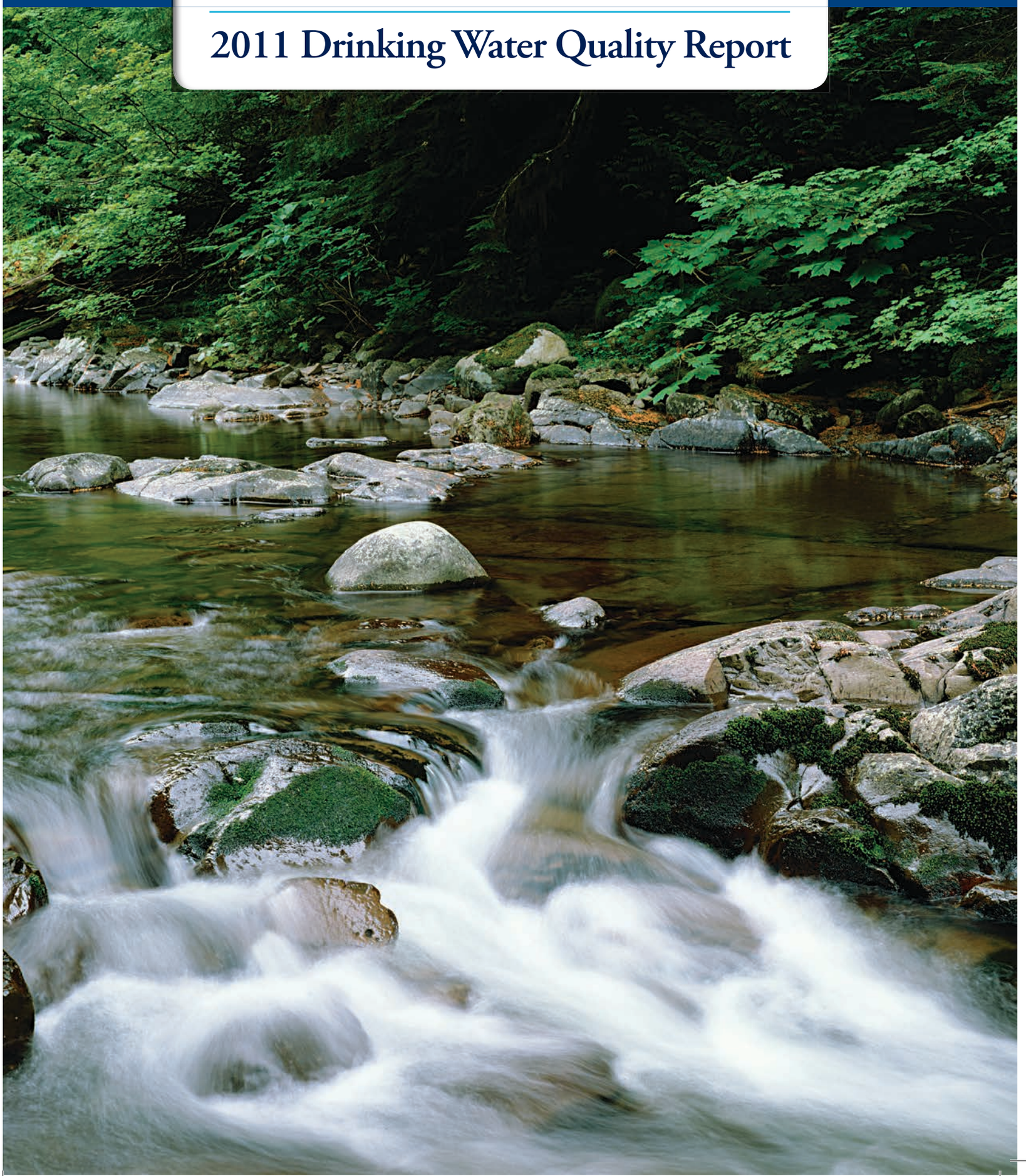
Eric Winiecki

Drinking Water Enforcement Coordinator

EPA Region 10(Note: Highlighting is ours)

PORTLAND WATER BUREAU

2011 Drinking Water Quality Report



PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

From Commissioner Randy Leonard

I am pleased to share the 2011 Drinking Water Quality Report with you. The Portland Water Bureau produces this report every year as mandated by the federal government. The report provides you with an easy-to-understand overview of your drinking water.

One thing you might note is that the Water Bureau monitors Portland's drinking water for more than 200 regulated and unregulated contaminants. That makes me feel incredibly confident in the water we serve and the water you drink. Portland's water is some of the highest-quality drinking water in the world. High quality is the Water Bureau way. It's the Portland way.

I urge you to take a minute to look through this report; learn about your water system and some of what goes into delivering water to your tap. Learn why we believe, "From forest to faucet, the Portland Water Bureau delivers the best drinking water in the world!"

Randy Leonard
Commissioner-In-Charge

From the Administrator

Since 1997, the federal government has required municipal water providers to send customers a yearly report detailing their water system. This report, the 2011 Drinking Water Quality Report, is essentially the nutritional label for the substance you probably consume more than any other – water.

If you have questions or comments about this, please call Portland Water Bureau Customer Service at 503-823-7770.
We welcome your interest in Portland's water system.

David G. Shaff
Administrator

Frequently Asked Questions About Water Quality

Is my water treated by filtration?
No. Bull Run water is not filtered. The Bull Run source meets the filtration avoidance criteria of the Surface Water Treatment Rule. The State approved Portland's compliance with these criteria in 1992. Portland continues to meet these criteria on an ongoing basis.

Does the Portland Water Bureau add fluoride to drinking water?
No. The Portland Water Bureau does not add fluoride to the water. Fluoride is a naturally occurring trace element in surface and groundwater. The U.S. Public Health Service and the Centers for Disease Control and Prevention consider the fluoride levels in Portland's water sources to be lower than optimal for the prevention of tooth decay. You may want to consult with your dentist about fluoride treatment to help prevent tooth decay, especially for young children.

Is Portland's water soft or hard?
Portland's water is very soft. The hardness of Bull Run water is typically 4-13 parts per million (ppm) – approximately ½ a grain of hardness per gallon. Portland's groundwater hardness is approximately 86 ppm (about 5 grains per gallon), which is considered moderately hard.

What is the pH of Portland's water?
The pH of Portland's drinking water typically ranges from 7.2 to 8.2.

Are sodium levels in Portland's drinking water affecting my health?
There is currently no drinking water standard for sodium. Sodium is an essential nutrient. Sodium in Portland's water typically ranges between 2 and 8 ppm, a level unlikely to contribute to adverse health effects.

Who can I call about water quality or pressure concerns?
The Water Line, **503-823-7525**, can answer your questions and concerns about water quality or pressure. The Water Line is available Monday–Friday from 8:30 a.m.– 4:30 p.m. If you have an emergency after these hours, please contact the after-hours number at **503-823-4874**.

How can I get my water tested?
Contact the LeadLine at **503-988-4000** or **www.leadline.org** for information about free lead-in-water testing. For more extensive testing, private laboratories can test your tap water for a fee. Not all labs are accredited to test for all contaminants. For information about accredited labs, call the Oregon Health Authority, Oregon Environmental Laboratory Accreditation Program at **503-693-4122**.

Public Involvement Opportunities

The Portland Water Bureau provides a variety of public information, public involvement and community outreach opportunities. If you have questions about Portland Water Bureau meetings, projects, or programs, please contact Jimmy Brown, Community Involvement and Information Manager, at **503-823-3028**, or visit the Water Blog to learn more about the bureau or leave a comment: **www.portlandoregon.gov/water/blog**.

Drinking Water Treatment

The first step in the treatment process for Portland's drinking water is disinfection using chlorine. Next, ammonia is added to form chloramines which ensure that disinfection remains adequate throughout the distribution system.

The Portland Water Bureau also adds sodium hydroxide to increase the pH of the water to reduce corrosion of plumbing systems. This treatment helps control lead and copper levels at customers' taps, should these metals be present in home plumbing.

Water Testing

The Portland Water Bureau monitors for over 200 regulated and unregulated contaminants in drinking water, including pesticides and radioactive contaminants. All monitoring data in this report are from 2010 unless otherwise noted.
If a known health-related contaminant is not listed in this report, the Portland Water Bureau did not detect it in drinking water.

Collecting groundwater samples for water quality analysis.

Special Notice for Immuno-Compromised Persons

Some people may be more vulnerable to contaminants in drinking water than the general population.

Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at-risk from infections. These people should seek advice about drinking water from their health-care providers. Environmental Protection Agency and Centers for Disease Control and Prevention guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the Safe Drinking Water Hotline at **800-426-4791**.

What the EPA Says About Drinking Water Contaminants

Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency's Safe Drinking Water Hotline at **800-426-4791** or at **www.epa.gov/safewater**.

The sources of drinking water (both tap water and bottled water) include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and, in some cases, radioactive material, and can pick up substances resulting from the presence of animals or from human activity.

Contaminants in drinking water sources may include:

Microbial contaminants, such as viruses and bacteria, which may come from wildlife or septic systems

Inorganic contaminants, such as salts and metals, which can occur naturally or result from urban stormwater runoff, industrial or domestic wastewater discharges or farming

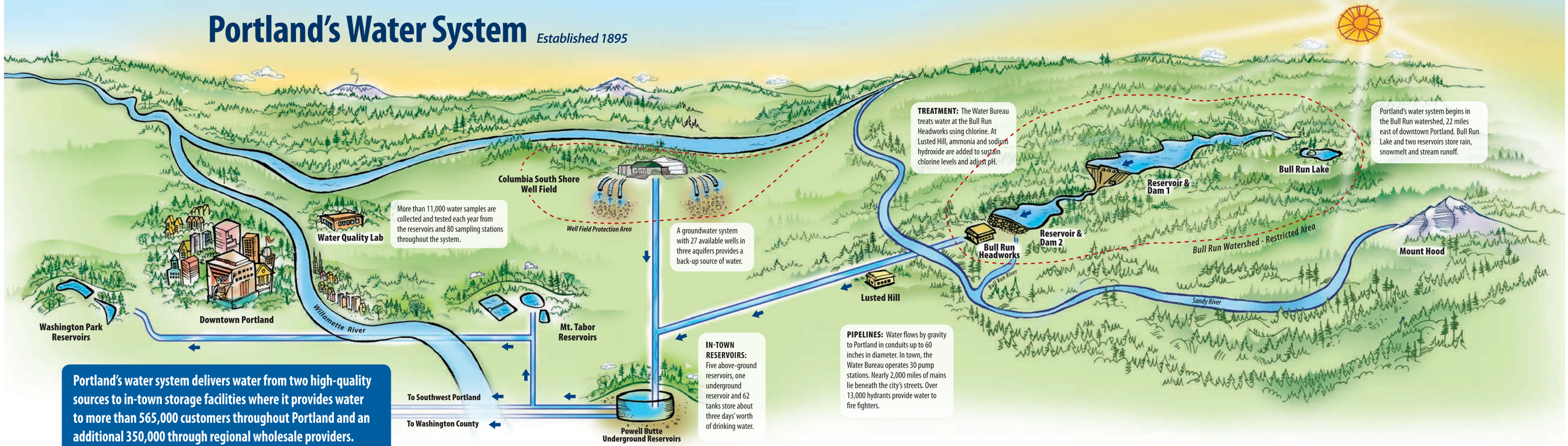
Pesticides and herbicides, which may come from a variety of sources such as farming, urban stormwater runoff and home or business use

Organic chemical contaminants, including synthetic and volatile organic chemicals, which are byproducts of industrial processes, and can also come from gas stations, urban stormwater runoff and septic systems

Radioactive contaminants, which can occur naturally

In order to ensure that tap water is safe to drink, the EPA has regulations that limit the amount of certain contaminants in water provided by public water systems and require monitoring for these contaminants. Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health.

Portland's Water System *Established 1895*



Benson Bubblers are Portland's iconic drinking fountains. The City currently maintains 52 of the four-bowl fountains and 74 one-bowl variations. The installation of the four-bowl fountains is limited to certain downtown boundaries so as not to diminish the uniqueness of them.

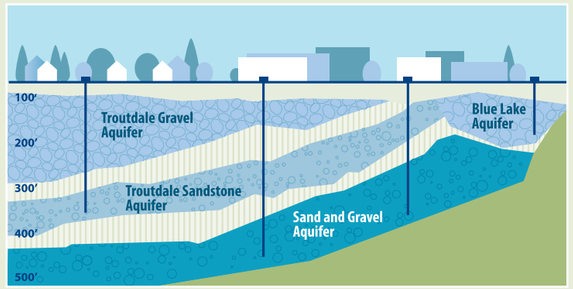
The Bull Run Watershed is a surface water supply within the Bull Run Watershed Management Unit located in the Mt. Hood National Forest. A geological ridge separates the watershed from Mount Hood. Current regulations, and the availability of the Columbia South Shore Well Field, allow Portland to meet federal drinking water standards without filtering this high-quality Bull Run water supply. The watershed has an area of 102 square miles, and typically receives 80-170 inches of rainfall a year. The heaviest rains occur from late fall through spring. Two reservoirs store water for use year-round, particularly during the dry summer months.

The watershed is only used for producing drinking water. Federal laws restrict public entry. No recreational, residential or industrial uses occur within its boundaries. The Portland Water Bureau carefully monitors water quality and quantity. The Oregon Health Authority Drinking Water Program regularly inspects the watershed and related treatment and distribution facilities.

The Portland Water Bureau has completed a Source Water Assessment for the Bull Run water supply to comply with the 1996 Safe Drinking Water Act amendments. The only contaminants of concern for the Bull Run water supply are naturally occurring microbial contaminants such as *Giardia lamblia, Cryptosporidium,* fecal coliform bacteria, and total coliform bacteria. These organisms are found in virtually all freshwater ecosystems and may be present in the Bull Run supply at very low levels. The Bull Run supply complies with all applicable state and federal regulations for source water, including the 1989 Surface Water Treatment Rule filtration-avoidance criteria. The Source Water Assessment report is available at **www.portlandoregon.gov/water** and by calling **503-823-7404**.

The Columbia South Shore Well Field provides high-quality drinking water from groundwater production wells located in three different aquifers. In 2010, the City of Portland supplemented the Bull Run drinking water supply with approximately 28 million gallons of groundwater over a 6-day period beginning on August 9th. This was done as part of a groundwater maintenance exercise.

Portland has a long history of groundwater protection. The groundwater protection area encompasses portions of Portland, Gresham and Fairview. Together, these cities regulate businesses in the groundwater protection area to prevent hazardous material spills that could seep into the ground. The cities also educate local residents on what can be done to help protect groundwater with events such as Aquifer Adventure, Cycle the Well Field and Groundwater 101. To learn more about Portland's groundwater protection program, upcoming events and how to protect groundwater, visit **www.portlandoregon.gov/water/groundwater** or call **503-823-7404**.



There are 27 usable wells capable of pumping water from three aquifers on the south shore of the Columbia River. The well field serves as a backup water supply during turbidity events and emergencies and when the bureau needs additional summer supply. The well field can produce up to 102 million gallons of water per day.

The Clackamas River Water District, City of Gresham, City of Lake Oswego, Rockwood Water People's Utility District, the Sunrise Water Authority and the Tualatin Valley Water District provide drinking water to some Portland customers who live near service area boundaries. Customers who receive water from these providers will also receive detailed water quality reports about these sources in addition to this report.

Regulated Contaminants Detected in 2010

Regulated Contaminant	Minimum Detected	Maximum Detected	Maximum Contaminant Level (MCL), Treatment Technique or Maximum Residual Disinfectant Level (MRDL)	Maximum Contaminant Level Goal (MCLG) or Maximum Residual Disinfectant Level Goal (MRDLG)	Sources of Contaminant
SOURCE WATER FROM THE BULL RUN WATERSHED					
Turbidity	0.23 NTU	2.0 NTU	Cannot exceed 5 NTU more than two times in twelve months	Not Applicable	Erosion of natural deposits
Giardia	Not Detected	8 samples of 10 liters each had 1 *Giardia* cyst	Treatment technique required: Disinfection to kill 99.9% of cysts	Not Applicable	Animal wastes
Fecal Coliform Bacteria	Not Detected	3 samples each had 4 bacterial colonies (100% of samples had 20 or fewer bacterial colonies per 100 milliliters of water)	At least 90% of samples measured during the previous six months must have 20 or fewer bacterial colonies per 100 milliliters of water	Not Applicable	Animal wastes
ENTRY POINTS TO THE DISTRIBUTION SYSTEM — from the Bull Run Watershed and Columbia South Shore Well Field					
NUTRIENTS					
Nitrate Nitrogen	0.01 parts per million	0.09 parts per million	10 parts per million	10 parts per million	Erosion of natural aquifer deposits; animal wastes
METALS AND MINERALS					
Antimony	<0.05 parts per billion	0.12 parts per billion	6 parts per billion	6 parts per billion	Found in natural deposits
Arsenic	<0.5 parts per billion	1.4 parts per billion	10 parts per billion	0 parts per billion	
Barium	0.00079 parts per million	0.00959 parts per million	2 parts per million	2 parts per million	
Chromium (total)	<0.2 parts per billion	0.3 parts per billion	100 parts per billion	100 parts per billion	
Copper[1]	<0.03 parts per million	0.0036 parts per million	Not Applicable	1.3 parts per million	
Fluoride	<0.050 parts per million	0.13 parts per million	4 parts per million	4 parts per million	
Lead	<0.02 parts per billion	0.15 parts per billion	Not Applicable	0 parts per billion	
RADIONUCLIDES					
Gross Beta[2]	3.4 picocuries per liter	3.4 picocuries per liter	50 picocuries per liter [3]	0 picocuries per liter	From man-made sources and natural deposits
DISTRIBUTION SYSTEM OF RESERVOIRS, TANKS AND MAINS					
MICROBIOLOGICAL CONTAMINANTS					
***E. Coli* Bacteria**	Not Detected	Routine samples in April and June had detectable *E. coli* bacteria	A routine sample and a repeat sample are total coliform positive, and one is also *E. coli* positive	0% of samples with detectable *E. coli* bacteria	Human and animal waste
Total Coliform Bacteria	Not Detected	6 samples out of 248 in October (2.42 %) had detectable coliform bacteria	Must not detect coliform bacteria in more than 5.0% of samples in any month	0% of samples with detectable coliform bacteria	Found throughout the environment
DISINFECTION BYPRODUCTS					
TOTAL TRIHALOMETHANES					
Running Annual Average of All Sites	21 parts per billion		80 parts per billion	Not Applicable	Byproduct of drinking water disinfection
Single Result at Any One Site	15 parts per billion	30 parts per billion	Not Applicable		
HALOACETIC ACIDS					
Running Annual Average of All Sites	25 parts per billion		60 parts per billion	Not Applicable	Byproduct of drinking water disinfection
Single Result at Any One Site	13 parts per billion	36 parts per billion	Not Applicable		
DISINFECTANT RESIDUAL					
Total Chlorine Residual	0.1 parts per million	2.2 parts per million	4 parts per million	4 parts per million	Chlorine and ammonia are used to disinfect water

Regulated Contaminant	90th Percentile Values	Number of Sites Exceeding Action Levels	Lead and Copper Rule Exceedance	Maximum Contaminant Level Goal (MCLG)	Sources of Contaminant
LEAD AND COPPER SAMPLINGS AT HIGH-RISK RESIDENTIAL WATER TAPS					
Copper	0.34 parts per million	0 of 112 samples exceeded the copper action level of 1.3 parts per million	More than 10% of the homes tested have copper levels greater than 1.3 parts per million	1.3 parts per million	Corrosion of household and commercial building plumbing systems
Lead	12 parts per billion	10 of 112 samples (8.9%) exceeded the lead action level of 15 parts per billion	More than 10% of the homes tested have lead levels greater than 15 parts per billion	0 parts per billion	Corrosion of household and commercial building plumbing systems

1 *During the year, two different methods with different method reporting limits (MRLs) were used to analyze copper. The sample with results of <0.03 was analyzed by the method with the less sensitive MRL.*

2 *These results are from 2009. The Oregon Health Authority – Drinking Water Program allows water utilities to monitor for some contaminants less than once per year because the concentrations of these contaminants do not change frequently.*

3 *The MCL for gross beta is 4 mrem/yr. EPA considers 50 picocurries per liter to be the level of concern for gross beta.*

Unregulated Contaminants Detected in 2010

Contaminant	Minimum Detected	Average Detected	Maximum Detected	Sources of Contaminant
ENTRY POINTS TO THE DISTRIBUTION SYSTEM — from the Bull Run Watershed and Columbia South Shore Well Field				
Nickel	<0.2 parts per billion	<0.2 parts per billion	0.7 parts per billion	Found in natural aquifer deposits
Radon	310 picocuries per liter	310 picocuries per liter	310 picocuries per liter	Found in natural aquifer deposits
Sodium	2.5 parts per million	8.5 parts per million	24.4 parts per million	Added to water during treatment Erosion of natural deposits
Vanadium	4.9 parts per billion	4.9 parts per billion	4.9 parts per billion	Found in natural aquifer deposits

*See **Notes on Regulated and Unregulated Contaminants** for more information.*

Definitions

Action Level
The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.

Maximum Contaminant Level or MCL
The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

Maximum Contaminant Level Goal or MCLG
The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

Maximum Residual Disinfectant Level or MRDL
The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Maximum Residual Disinfectant Level Goal or MRDLG
The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Part Per Billion
One part per billion corresponds to one penny in $10,000,000 or approximately one minute in 2,000 years.

Part Per Million
One part per million corresponds to one penny in $10,000 or approximately one minute in two years. One part per million is equal to 1,000 parts per billion.

Picocuries Per Liter
Picocurie is a measurement of radioactivity. One picocurie is a trillion times smaller than one curie.

Treatment Technique
A required process intended to reduce the level of a contaminant in drinking water.

Notes on Regulated Contaminants

Turbidity
The Bull Run is an unfiltered surface water supply. The rules for public water systems have strict standards for unfiltered surface water supplies. Turbidity levels in unfiltered water must not exceed 5 NTU (nephelometric turbidity units) more than two times in a twelve-month period. The typical cause of turbidity is sediment suspended in the water that can interfere with disinfection and provide a medium for microbial growth. Large storm events can result in increased turbidity, causing the Portland Water Bureau to shut down the Bull Run system and serve water from the Columbia South Shore Well Field.

Giardia
Wildlife in the watershed may be hosts to *Giardia lamblia*, the organism that causes giardiasis. The Portland Water Bureau uses chlorine to control these organisms.

Fecal Coliform Bacteria
The presence of fecal coliform bacteria in source water indicates that water may be contaminated with animal wastes. The Portland Water Bureau uses chlorine to kill these bacteria.

Nitrate - Nitrogen
Nitrate, measured as nitrogen, can support microbial growth (bacteria and algae). Nitrate levels exceeding the standards can contribute to health problems.

Antimony, Arsenic, Barium, Chromium (total), Copper, Fluoride and Lead
These metals are elements found in the earth's crust which can dissolve into water that is in contact with natural deposits. At the levels found in Portland's drinking water, they are unlikely to contribute to adverse health effects. There is no maximum contaminant level (MCL) for copper or lead at the entry point to the distribution system. Copper and lead are regulated at customers' taps. For more information see ***Chromium-6*** on page 10 and ***Reducing Exposure to Lead*** on page 8.

Gross Beta
Certain elements are radioactive and may emit forms of radiation known as photons and beta radiation. Gross beta was detected in Portland's groundwater at the entry point to the distribution system in 2009. At levels detected in Portland's drinking water, gross beta is unlikely to contribute to adverse health effects.

***E. Coli* Bacteria**
E. coli are bacteria that indicate that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches or other symptoms. The microbes may pose a special health risk for infants, young children, some of the elderly and people with severely compromised immune systems. The Portland Water Bureau uses chlorine to kill these bacteria.

Total Coliform Bacteria
Coliforms are bacteria which are naturally present in the environment and are used as an indicator that other potentially-harmful bacteria may be present.

Disinfection Byproducts
During disinfection, certain byproducts form as a result of chemical reactions between chlorine and naturally occurring organic matter in the water. These byproducts can have negative health effects. Trihalomethanes and haloacetic acids are regulated disinfection byproducts which have been detected in Portland's water. The disinfection process is carefully controlled to keep byproduct levels low.

Total Chlorine Residual
Total chlorine residual is a measure of free chlorine and combined chlorine and ammonia in our distribution system. Chlorine residual is necessary to maintain disinfection throughout the distribution system. Adding ammonia to chlorine results in a more stable disinfectant and helps to minimize the formation of disinfection byproducts.

Notes on Unregulated Contaminants

Unregulated contaminant monitoring helps the EPA to determine where certain contaminants occur and whether it needs to regulate those contaminants in the future.

Nickel
Nickel is a metal found in the earth's crust; it can dissolve into water that is in contact with natural deposits. There is currently no maximum contaminant level for nickel. At the levels found in Portland's drinking water, it is unlikely to contribute to adverse health effects.

Radon
Radon is a naturally occurring radioactive gas that cannot be seen, tasted or smelled. Radon has not been detected in the Bull Run supply. It has been detected at varying levels in Portland's groundwater supply. For information about radon, call the EPA's Radon Hotline **(800-SOS-RADON)** or **www.epa.gov/radon/rnwater.html**.

Sodium
Sodium is a metal found in the Earth's crust; it can dissolve into water that is in contact with natural deposits or added to water during treatment. There is currently no drinking water standard for sodium. Sodium is an essential nutrient. At the levels found in drinking water, it is unlikely to contribute to adverse health effects.

Vanadium
Vanadium is a metal found in the earth's crust, which can dissolve into water that is in contact with natural deposits. Based on concerns regarding vanadium as a potential emerging contaminant, the Portland Water Bureau tested water from the Columbia South Shore Well Field for vanadium in 2010. All of the results for vanadium were below the 50 parts per billion Notification Level set by the State of California. At these levels it is unlikely to contribute to adverse health effects.

Reducing Exposure to Lead

Portland has removed all known lead service connections from its distribution system. Exposure to lead through drinking water is possible if materials in a building's plumbing contain lead. The level of lead in water can increase when water stands in contact with lead-based solder and brass faucets containing lead.

If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. The Portland Water Bureau is responsible for providing high-quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your drinking water, you may wish to request a free lead-in-water test from the LeadLine. Information on lead in drinking water, testing methods and steps you can take to minimize exposure is available from the **LeadLine, 503-988-4000**, **www.leadline.org** or the Safe Drinking Water Hotline **800-426-4791**, **www.epa.gov/safewater/lead**.

People are exposed to lead in many other ways. In the Portland area, dust from paint in homes built before 1978 is the most common source of exposure to lead. Other sources include soil, pottery, traditional folk medicines or cosmetics, some sports equipment such as fishing weights and ammunition, and some occupations and hobbies.

Corrosion Treatment

The Portland Water Bureau's corrosion control treatment reduces corrosion in plumbing by increasing the pH of the water. Comparison of monitoring results with and without pH adjustment shows more than 50 percent reduction in lead and 80 percent reduction in copper at the tap with pH adjustment.

Water Testing

Twice each year the Portland Water Bureau monitors for lead and copper in tap water from a sample group of more than 100 homes. These are homes in Portland's service area where the plumbing is known to contain lead solder which is more likely to contribute to elevated lead levels. These houses represent a worst-case scenario for lead in water. Samples are collected after the water has been standing in the household plumbing for more than 6 hours. A Lead and Copper Rule exceedance for lead occurs when more than 10 percent of these homes exceed the lead action level of 15 parts per billion. In the most recent round of testing, less than 10 percent of homes exceeded the lead action level.

If you are concerned that your home tap water may have lead, call the LeadLine for a free lead-in-water test kit and to learn ways to reduce your exposure to all sources of lead. This program targets testing the water in households most at-risk from lead in water. These are homes built between 1970 and 1985 with pregnant women or children ages six or younger in the home.

Easy steps to avoid possible exposure to lead in drinking water

- **Run your water to flush out lead.** If the water has not been used for several hours, run each tap for 30 seconds to 2 minutes or until it becomes colder before drinking or cooking. This flushes water which may contain lead from the pipes.
- **Use cold, fresh water for cooking and preparing baby formula.** Do not cook with or drink water from the hot water tap; lead dissolves more easily into hot water. Do not use water from the hot water tap to make baby formula.
- **Do not boil water to remove lead.** Boiling water will not reduce lead.
- **Consider using a filter.** Check whether it reduces lead – not all filters do. Be sure to maintain and replace a filter device in accordance with the manufacturer's instructions to protect water quality. Contact NSF International at **800-NSF-8010** or **www.nsf.org** for information on performance standards for water filters.
- **Test your water for lead.** Call the **LeadLine** at **503-988-4000** to find out how to get a **FREE** lead-in-water test.
- **Test your child for lead.** Ask your physician or call the **LeadLine** to find out how to have your child tested for lead. A blood lead level test is the only way to know whether your child is being exposed to lead.
- **Regularly clean your faucet aerator.** Particles containing lead from solder or household plumbing can become trapped in your faucet aerator. Regular cleaning every few months will remove these particles and reduce your exposure to lead.
- **Consider buying low-lead fixtures.** New brass faucets, fittings and valves, may contribute to lead in your drinking water. Federal law currently allows brass fixtures, such as faucets, to contain up to 8% lead. These fixtures are labeled as "lead-free." When buying new fixtures, consumers should seek out those with the lowest lead content. Visit **www.nsf.org** to learn more about lead content in plumbing fixtures. See ***Reduction of Lead in Drinking Water Act*** on page 10 for more information.

Leadline - 503-988-4000
Call the **LeadLine** or visit **www.leadline.org** for information about lead hazards, free lead-in-water testing, free childhood blood lead testing and referrals to other lead reduction services.
www.leadline.org

The LT2 Rule

In January 2006, the federal Environmental Protection Agency (EPA) issued a drinking water rule called the Long Term 2 Enhanced Surface Water Treatment Rule (LT2) principally to reduce the risks of illness from *Cryptosporidium*, a protozoan parasite found in the intestines and fecal material of mammals. If ingested, infectious forms of *Cryptosporidium* can cause cryptosporidiosis which results in gastrointestinal illness in humans and more serious illness in immunocompromised populations (see ***Special Notice for Immuno-Compromised Persons*** on page 2 in this report). The LT2 rule has two principal requirements which affect Portland's water system: 1) the installation of additional treatment processes to address *Cryptosporidium* in Bull Run source water by 2014, and 2) ending the use of uncovered finished drinking water reservoirs in Mt. Tabor and Washington Parks.

Compliance with Additional Treatment Requirements

Portland's Request for a Treatment Variance

The Safe Drinking Water Act enables Portland to apply for a variance to the surface water treatment requirements of the LT2 rule if it can demonstrate that such treatment is not necessary to protect public health. In December 2009, the Water Bureau began a comprehensive water sampling program to investigate whether *Cryptosporidium* is a public health risk in the Bull Run watershed. For a one year period the City conducted intensive testing of water samples from its untreated source water. After collecting 449 water samples at the water supply intake and an additional 315 samples from several upstream watershed locations, zero instances of *Cryptosporidium* were detected. These results build on those from previous testing for *Cryptosporidium* in the Bull Run watershed. Although *Cryptosporidium* has been detected in the past, monthly tests from the watershed have not detected the pathogen since August 2002.

The absence of *Cryptosporidium* in the City's water quality sampling results is consistent with the natural conditions and legal protections in place for the Bull Run watershed which serve to reduce the risk of *Cryptosporidium* exposure for Portland's drinking water.

No Cryptosporidium *were found in the year-long water quality monitoring in support of a variance request to the treatment requirements of the LT2 rule.*

Because public entry and any associated recreational, agricultural or development activities are prohibited in the Bull Run watershed, wildlife is the only significant potential *Cryptosporidium* source in the watershed. Analysis of wildlife in the predominant old growth forest conditions in the watershed indicates that total population density of animals is relatively low and that incidence of animals shedding *Cryptosporidium* in the watershed is extremely low. From August 2009 through December 2010, the Water Bureau collected and analyzed 251 wildlife scat samples in and around the watershed for the presence of *Cryptosporidium*. Only a single sample tested positive containing just two individual *Cryptosporidium* oocysts.

Vegetation and hydrologic conditions in the watershed may further reduce the limited risk of *Cryptosporidium* contamination by restricting the movement of potential pathogens through the watershed. The dense forest canopy, low to moderate rainfall intensities, and porous soil that have a high capacity for infiltration result in most water flow occurring below the ground surface. This flow through vegetation and soil can trap pathogens, preventing them from reaching streams and the drinking water supply reservoirs.

An analysis of available health related data appears to show that the majority of the reported cases of cryptosporidiosis in the Portland region are sporadic in nature and that there was no evidence which would suggest that drinking water has been a significant source of cryptosporidiosis. This health data shows that under current conditions in the Bull Run, adding additional water treatment is not likely to result in a measurable decrease in the occurrence of reported cases of cryptosporidiosis in the Bull Run service area.

Based on these sampling results and analysis, the City intends to submit a treatment variance request to the Oregon Drinking Water Program in June 2011 and anticipates hearing back regarding its request by the end of 2011.

UV Treatment as a Last Resort

In the event the Oregon Drinking Water Program rejects the City's request for a treatment variance, the City is also in the process of designing an ultraviolet light (UV) treatment facility to meet the treatment requirements of the LT2 rule. The UV design phase is scheduled to be completed by the end of 2011 when a final decision on the City's eligibility for a treatment variance is anticipated. This timing will enable the City to meet the April 1, 2014 deadline for constructing the UV treatment facility if it proves to be necessary.

Uncovered Finished Drinking Reservoirs: Storage Replacement Underway

In November 2009, the City requested direction from EPA regarding the possibility of a variance to the uncovered finished drinking reservoir requirements of the LT2 rule. In December 2009, the EPA replied that no such option exists. As required by the LT2 Rule, the City is currently implementing a multi-year plan to develop alternative enclosed storage and end the use of its open finished drinking water reservoirs in Mt. Tabor and Washington Parks by December 31, 2020. For updates on the Portland Water Bureau's response to the LT2 rule visit **www.portlandonline.com/water/LT2**.

Developments in Water Quality

Chromium-6

The progress on research into chromium-6 made news in December 2010 when the Environmental Working Group, an environmental advocacy group, said it had found chromium-6 in the water of 31 cities and urged the EPA to adopt new rules regarding the regulation of this compound.

Currently, there are no federal regulations or requirements to test for chromium-6 in drinking water. In January 2011, the EPA issued recommendations for enhanced chromium-6 monitoring of surface water supplies quarterly and groundwater supplies semi-annually. Portland is voluntarily following these recommendations and has contracted with an accredited laboratory to conduct chromium-6 analysis of the Bull Run water supply quarterly and groundwater in summer 2011.

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium can exist in a variety of forms, but is typically found in the environment and drinking water in two main forms: trivalent chromium (chromium-3) and hexavalent chromium (chromium-6). Chromium-3 occurs naturally in the environment and is an essential human dietary nutrient. Chromium-6 is the more toxic form and is generally associated with industrial processes. Recent studies have shown that ingestion of drinking water or food containing chromium-6 may cause cancer in laboratory mice and rats. Chromium can transform from one form to another in water and soil, depending on the conditions present.

EPA's final toxicological review of chromium-6 is expected in 2011. This risk assessment will form the basis of any regulations that may be developed. PWB will continue to work closely with the EPA and with organizations such as the American Water Works Association to monitor this issue as developments emerge.

Reduction of Lead in Drinking Water Act

In December 2010, US Congress passed the Reduction of Lead in Drinking Water Act. The new law will reduce the amount of lead in new household plumbing fixtures. Currently, "lead-free" plumbing fixtures can contain up to 8% lead. Under the new law the maximum lead content allowed will be 0.25%. The new regulations only apply to new faucets and fixtures and will take effect in three years. The new law will not have any effect on existing home plumbing. The Portland Water Bureau supports the passage of this law and submitted a letter of support for passage of the bill. Household plumbing is the largest source of lead in water in the Portland area.

The Portland Water Bureau encourages customers to carefully choose new faucets and fixtures for their home. Many manufacturers are already producing components that meet the new standards. These components can most easily be purchased through retailers in California, Vermont and Maryland where the new standards have already been implemented. By 2014, all components sold in Portland will meet the higher standards.

The Portland Water Bureau has 184 water quality sampling stations throughout the distribution system to monitor water quality on a regular basis.

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Portland, Oregon 97204

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POSTAL CUSTOMER

Drinking water regulations require the city to mail this information to customers each year — It's the law.

Most of the language is also required – Congress and the EPA want to be sure that people know what is in their drinking water. The Portland Water Bureau agrees.

The Portland Water Bureau makes significant efforts to produce this complex information readable and at a low cost. ***The Portland Water Bureau produced and mailed this report for 29 cents each.***

ROMAN JOHNSTON

Dam 1 in the Bull Run watershed

Printed on recycled paper
JUNE 2011

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FOR ADDITIONAL INFORMATION

Oregon Health Authority – Drinking Water Program:
971-673-0405
www.public.health.oregon.gov/HealthyEnvironments/DrinkingWater

The City of Portland will provide auxiliary aids/services to persons with disabilities. To request an ADA accommodation, please call 503-823-7404 or by TTY at 503-823-6868. Copies of this report are available in Braille, large format type and on the Portland Water Bureau's website — www.portlandoregon.gov/water.

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Para obtener una copia de este reporte en español, por favor llame al **503-823-7770** o visite www.portlandoregon.gov/water

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