King County Groundwater Protection Program

Ambient Groundwater Monitoring

2001 – 2004 Results

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King County

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EXECUTIVE SUMMARY

The King County Department of Natural Resources and Parks (DNRP) has been conducting ambient groundwater monitoring during the period 2001 through 2004. During 2001 – 2004 the ambient groundwater monitoring program focused on the four Groundwater Management Areas (GWMAs) listed below. The boundaries of the four GWMAs are shown on Figure 1.

- East King County
- Issaquah Creek Valley
- Redmond-Bear Creek Valley
- Vashon-Maury Island

Water levels and water quality were monitored in wells in each of the GWMAs. Of 92 wells in the groundwater monitoring program, 24 wells were monitored only for water level and 11 wells were only sampled for water quality. The remaining 57 wells were monitored for water level and water quality.

Groundwater samples collected between 2001 and 2004 were analyzed for volatile and semivolatile organic compounds, chlorinated herbicides, metals, conventional water quality parameters, and microbiological parameters. The analytical results found insignificant concentrations of the organic compounds, including the herbicides, and analysis for these constituents was discontinued after 2001. Analysis for metals, conventional parameters, and microbiological parameters continued throughout the monitoring period. Five constituents—arsenic, nitrate, lead, sodium, and bacteria—are discussed in detail in this report, and detections of two additional constituents—iron and manganese—that may cause discoloration are noted.

Arsenic is a naturally occurring metal that was found at concentrations exceeding health-based levels in at least one well in three of the four GWMAs (Issaquah Creek Valley is the exception). There are also human sources of arsenic in the environment. East King County has the most wells with arsenic concentrations exceeding the Maximum Contaminant Level (MCL). Regional studies performed by the U.S. Geological Survey indicate that elevated levels of arsenic is common in the Pacific Northwest due to leaching of the metal from rocks and soil. The concentrations of arsenic have remained essentially constant over the monitoring period.

Nitrate in groundwater has both natural and human sources. Only one sample from one well in the monitoring program had a nitrate concentration above the MCL. Nitrate concentrations tend to be higher in shallower wells, which may indicate that the nitrate is from surface and near-surface sources, such as septic systems and fertilizer use. The concentrations of nitrate have remained essentially constant over the monitoring period.

Lead is a naturally occurring metal that is leached from rocks into groundwater. As with arsenic, there are also human sources of lead in the environment. Lead was not found at concentrations exceeding the MCL. Concentrations of lead in tap water decreased prior to the 2001 – 2004 monitoring period and remained essentially constant during the 2001 – 2004 monitoring period.

Sodium is another naturally occurring metal that is commonly found in groundwater. Although sodium at concentrations commonly found in groundwater is not associated with adverse health effects for most people, some people—such as those with hypertension or kidney disease—may be advised to avoid consuming water with concentrations of sodium exceeding 20 milligrams per liter (mg/l). In the four GWMAs, 20 of the 92 wells had at least one sample with a measured concentration of sodium greater than 20 mg/l.

Both total and fecal coliform bacteria were measured in groundwater samples. The bacteria counted in a total coliform analysis are common in the environment and are generally harmless. Fecal coliform bacteria are associated with a variety of health effects. Fecal coliform were detected in only one sample out of the entire monitoring program.

The conclusions of the 2001 – 2004 monitoring programs are that water quality is generally at least as good as MCLs. The results of the water-level monitoring indicate that water levels are stable in the areas monitored. Based on these findings, the DNRP recommends continuing and modifying the monitoring program. The recommended modifications are to expand the monitoring network to double the number of wells sampled and to focus the analytical program on those constituents that would indicate water quality concerns. Based on the results of the monitoring program, specific wells could be identified for enhanced analytical programs.

1.0. INTRODUCTION

1.1 Purpose

The King County Department of Natural Resources and Parks (DNRP) has been conducting ambient groundwater monitoring during the period 2001 through 2004. This report presents the work completed, findings, and recommendations resulting from the monitoring effort.

The DNRP is designated by ordinance as the lead agency for all groundwater related work within King county. Primary DNRP groundwater management responsibilities include: Interagency Coordination, Groundwater Protection Planning, Data Collection/Management, King County Groundwater Policy Establishment, Groundwater Stewardship, and Program Administration. During 2001 – 2004 the ambient groundwater monitoring program focused on the four Groundwater Management Areas (GWMAs) listed below. The boundaries of the four GWMAs are shown on Figure 1.

- East King County
- Issaquah Creek Valley
- Redmond-Bear Creek Valley
- Vashon-Maury Island

Groundwater has several key beneficial uses in the four designated GWMAs, including public and private drinking water supplies, irrigation supplies, and discharge to area rivers and lakes. The continued suitability of groundwater for these beneficial uses depends on maintaining the quality and available quantity of groundwater.

The ambient groundwater monitoring program is designed to identify potential water quality and quantity problems that could pose a health risk or threat to the beneficial uses of groundwater. The program monitors a network of private and public supply wells that are representative of groundwater supplies in each of the four management areas. The success of the monitoring program is largely due to a high level of cooperation and support from the City governments, public water purveyors, and private citizens.

Section 2 of this report describes the groundwater sampling protocols and the laboratory testing procedures. Section 3 compares the groundwater quality data with human health standards and provides a historical comparison with previous water quality data. Section 4 presents the results of water level monitoring. Section 5 ties together the findings of the monitoring program and identifies focus areas for continued monitoring.

1.2 Locations Sampled / Timing of Sampling Rounds

The Groundwater Protection Program (GWPP) monitored 68 wells for water quality and limited water level data since 2001. The locations of the wells distributed amongst the four GWMAs are shown on maps of the four GWMAs, Figures 2A, 2B, 2C, and 2D.

The wells monitored include a combination of wells owned by public water purveyors, and by private individuals who agreed to participate in the monitoring program.. On Vashon-Maury Island, an additional 24 wells were monitored for water level data only. All of the wells are listed on Table 1. Table 1 shows which wells are located in each of the four GWMAs, and indicates how the wells were monitored: water level data only, water quality data only, or both.

Prior to this monitoring effort, a detailed hydrogeologic evaluation of each of the GWMA was completed and presented in Groundwater Management Plan (GWMP) prepared by King County Groundwater Advisory Committees (EKC GWMP, 1998; ICV GWMP, 1998; RBC GWMP, 1998; and VMI GWMP, 1998). Additional information sources for some areas included past reports by the U.S. Geological Survey (USGS) (Water Resources Investigation Reports 92-4098 and 94-4082). The wells for the monitoring program in each GWMP were selected to evaluate the range of conditions within each area, including a range of depths and locations that are representative of a variety of potential non-point contamination sources.

The wells monitored in this water quality monitoring program were part of the GWMP for each area. Numerous water level locations on Vashon-Maury Island were not part of the GWMP, see Table 1 and Section 4. Although the wells selected have a wide range of depths, there are more shallow wells in the program because such wells are typically more susceptible to contamination than deep wells. The wells are located in areas that could be impacted by the use of agricultural chemicals, such as fertilizers, pesticides, and herbicides. Some of the wells on Vashon-Maury Island are in coastal areas that could be impacted by salt-water intrusion. Many of the wells are located on properties that have individual septic systems, a potential source of nitrate and bacterial contamination. However, the well network was designed to provide a general overview of groundwater quality in the four GWMAs and is not expected to provide warning of contamination from small-scale or point sources in the GWMAs.

The process of identifying appropriate wells for the monitoring network included extensive communication between DNRP staff and the well owners. Permission for monitoring access was obtained from each of the well owners. Each of the wells was evaluated to assure that the well piping and plumbing system provides accessibility for obtaining a representative sample. The field protocols for obtaining a representative sample are described in Section 2.

Sixty-eight of the 92 wells in the current monitoring program were also part of earlier King County monitoring networks. Comparison of the 2001 – 2004 data with the earlier testing results provides a historical comparison of water quality trends, which are described in Sections 3 and 5.

A summary of the schedule of sampling events at each of the GWMAs is listed on Table 2. There were a total of seven sampling events during the 2001 – 2004 period. The first four events occurred in 2001 and 2002 and included all four of the GWMAs. Events 5, 6, and 7 took place only in the East King County and Vashon-Maury Island GWMAs. Some of the events were scheduled so that water quality data would be obtained from all four of the GWMAs during the same period, such as event number two that occurred during November and December 2001, and event number four that took place during September and October 2002. Other events took place over a longer period, such as event number one, which extended from January through May 2001. The time required for each of the events was affected by several factors, including the number of wells to be sampled, and the number of field staff available to carry out the sampling.

2.0. PROCEDURES

The King County Groundwater Protection Program uses standard and documented procedures to collect data. The procedures are part of the project Quality Assurance and Quality Control (QAQC) program designed to maintain a consistent basis for comparing the data between well locations and sampling events. The QAQC procedures are described in the Sampling and Analysis Plans (SAP) for each of the four Groundwater Management Areas (EKC SAP, 2000; ISS SAP, 2001, RBC SAP, 2001; and VMI SAP, 2000). Adhering to standard sampling and analytical techniques is also necessary for comparing water quality data to Maximum Contaminant Levels (MCL) for drinking water. The field sampling, chain of custody, and laboratory testing protocols in the SAPs are summarized in the following sections.

2.1 Sampling Procedures

The goal of groundwater sampling is to collect a sample that is representative of groundwater quality from the aquifer. Therefore sampling protocols are designed to prevent changes to the groundwater chemistry that could be caused by sampling methods, sample storage, or transport.

To satisfy this objective, water samples are collected from a hose bib in the well distribution system as close to the wellhead as possible to avoid the possible chemical changes that could be caused by aeration in the house plumbing or the effects of chemical water softeners and other water treatment systems. Figure 3 is a plumbing diagram of a typical domestic well, showing the ideal sampling location.

Generally, a volume of water equal to three times the standing volume of water in the well is purged prior to collecting the sample. This is done to assure that the stagnant water in the well casing has been replaced by fresh groundwater from the aquifer prior to sampling. This is generally not a problem in the King County monitoring program, because all of the monitoring wells are also active supply wells. This means that most of the wells are pumped every day, minimizing the likelihood of stagnant water being present in the well during sampling.

During purging the field technician obtains frequent measurements of groundwater pH, conductivity, temperature, dissolved oxygen, and turbidity using portable field testing meters. The sample is not collected until the groundwater pH, conductivity, and temperature measurements have stabilized. For some wells, purging three full well volumes is impractical due to large casing volumes and slow pumping rates. In these cases, a minimum of one well volume is purged and then samples are collected once field parameters (pH, conductivity, temperature) have stabilized. The groundwater turbidity level should be less than 5 NTUs before the sample is collected.

At wells where the piping configuration or pressure at the wellhead prevents the sampling technician from directly filling sample bottles from the hose bib, samples are collected using laboratory cleaned tubing. Acid-rinsed tubing is used to collect samples for metals analyses, and sterile tubing is used to collect samples for biological analyses. All sampling equipment and containers are prepared in the laboratory, and precautions are taken to avoid contaminating samples during sample collection.

The sample bottles are carefully labeled with the numerical identifier, date, sampler's initials, and other information important to the testing laboratory. The samples are stored on ice in a shipping container. Because some the target analytes have short holding times, such as nitrate and bacteria; the samples are generally delivered to the testing laboratory at the end of each field day.

2.2 Analytical Laboratory Procedures

The analyses of samples from all the management areas are performed by the King County Environmental Laboratory except for analyses for organic halides, silica, and fluoride, which are performed by AmTest, Inc. under contract to the King County Environmental Laboratory. Groundwater samples are analyzed for selected metals, organic compounds, conventional water quality parameters (such as Total Dissolved Solids and alkalinity), and coliform bacteria (both total and fecal coliform). Analyses are performed on unfiltered water samples.

Samples from all four GWMAs were analyzed for metals and selected conventional parameters in all of the sampling events listed in Table 2. Organic compounds were sampled and analyzed only once during this monitoring program. This special sampling was done during the second sampling event (November – December 2001) unless the site was unavailable. Coliform analyses were performed during the first two events only unless the site was unavailable. Special sampling like organics and/or bacteria analyses were done in subsequent events if the sites were previously not sampled. Table 3 provides the complete list of analytes included in the program.

3.0. WATER QUALITY RESULTS

The 2001 – 2004 groundwater monitoring completed by King County DNRP provides a comprehensive assessment of groundwater quality in each of the four GWMAs. Appendices A - D contain tables with all of the water quality data generated for each of the four GWMAs during the period 2001 – 2004. For each of the four GWMAs, the appendix includes a separate table covering each of the following groups of water quality target analytes.

- Volatile Organic Compounds
- Semivolatile Organic Compounds
- Organic-Chlorinated Herbicides
- Metals
- Conventionals and Microbiology

The water quality tables in the Appendices identify each of the monitoring wells by a unique number that corresponds to the GWMA. Following is a list of prefixes used to identify the wells monitored in each of the GWMAs.

- East King County = EKC
- Issaquah Creek Valley = ISS
- Redmond-Bear Creek Valley = RBC
- Vashon-Maury Island = VAS or VMI

The reader can also use the prefixes to identify individual wells shown on the GWMA maps, Figures 2A, 2B, 2C, and 2D. The well numbers are also used to identify the wells on the water quality figures in report Sections 3 and 4.

Literally hundreds of water quality analyses were performed, resulting in thousands of data points. Because it would not be practical to discuss all of the water quality data, this report focuses on information that is most relevant to groundwater as a primary source of drinking water.

Table 2 lists the groundwater sampling events carried out in each of the GWMAs. The organic-chlorinated herbicides, volatile organics, semivolatile organics, and microbiological analyses were only performed in the 2001 monitoring events and on a limited number of wells in the June 2002 monitoring event. The organic analytes were not tested in 2003 and 2004 because there were only trace concentrations of a few contaminants detected in the 2001 and 2002 events. The metals and conventional classes of analytes were tested at one or more of the GWMAs throughout the 2001 – 2004 monitoring period. These classes of analytes contained the only contaminants that exceeded drinking water MCLs, and therefore received a higher frequency of monitoring.

3.1 General Characteristics

One of the primary reasons that groundwater is a popular source of drinking water is that groundwater normally has excellent quality and can be used directly from the well without treatment. Data from the 2001 – 2004 monitoring program shows that this is generally true in the four King County GWMAs. The water quality data indicate the presence of some contaminants originating from human activities, but generally not at concentrations that exceed drinking water quality standards. There are also some naturally occurring contaminants that impact groundwater quality, such as arsenic, and iron. In some cases these naturally occurring contaminants exceed current or future drinking water concentration limits. The following discussion focuses on the water quality characteristics that affect suitability for drinking water.

3.2 Comparison to Drinking Water Standards

The U.S. Environmental Protection Agency Region X (EPA), the Washington Department of Health, and King County agencies have adopted the Primary and Secondary Drinking Water MCLs promulgated under the Federal Safe Drinking Water Act. The Primary MCLs are established for those contaminants that have unacceptable human health effects. The Secondary MCLs are for contaminants that have aesthetic effects (such as taste, odor, color) or cosmetic effects, such as skin or tooth discoloration. The Primary and Secondary MCLs relevant to this project are listed on Table 3.

A review of Table 3 shows that MCLs have not been promulgated for all of the target water quality analytes tested in this program. However, MCLs do exist for many of the contaminants typically found in groundwater that has been impacted by man's activities.

The following sections focus on those analytes that currently exceed MCLs in the study area, have exceeded MCLs in pre-2001 studies, or have other characteristics of potential importance to water quality in the GWMAs.

3.2.1 Arsenic

Arsenic has been detected in groundwater in each of the four GWMAs, Appendices A – D. This is not unexpected since arsenic is a naturally occurring component of certain types of soil and rock in the Pacific Northwest. Although arsenic contamination can also be caused by some of man's activities, such as industrial manufacturing, the arsenic detected in King County groundwater is believed to be derived from natural leaching of arsenic from rocks and soil minerals (USGS Water Supply Paper 94-4082). Arsenic is chemically classified as a metal, and therefore is listed on the metals table for each GWMA in the appendix.

The EPA has determined that arsenic is a human carcinogen, that is, capable of causing cancer. The current arsenic drinking water MCL is 0.05 mg/l (milligrams of arsenic per liter of water).

This concentration is equivalent to 50 parts of arsenic in a million parts of water. The 0.05 mg/l MCL has been the drinking water limit for decades, but the MCL is going to change in 2006.

The arsenic MCL will be lowered to 0.01 mg/l for public drinking water supplies in 2006. This report therefore uses the imminent 0.01 mg/l MCL for comparison with the 2001 – 2004 water quality data. Lowering the arsenic MCL will mean that some public and private ground water supplies will no longer meet public drinking water quality standards.

Some of the wells in each of the GWMAs have had no detections of arsenic. Each of the GWMAs has wells with arsenic concentrations approaching or exceeding the 0.01mg/l MCL.

The East King County (EKC) GWMA had the most wells with arsenic concentrations exceeding the MCL. Seven of the 14 EKC wells in the monitoring program exceeded the arsenic MCL. Arsenic concentrations for five representative wells in the EKC GWMA are shown on Figure 4A. The lines plotted on Figure 4A represent arsenic concentrations for each of the monitoring events during the 2001 – 2004 period. Although the arsenic concentrations at each well have varied during the monitoring period, the average arsenic concentration at each well has remained fairly constant.

Issaquah Creek Valley (ISS) is the only GWMA that had no wells exceeding the MCL. As shown on Figure 4B, a few wells, such as ISS-15 had arsenic concentrations approaching, but not exceeding the MCL.

The Redmond-Bear Creek (RBC) GWMA had only one well with arsenic concentrations exceeding the MCL. Well RBC-05 had arsenic concentrations between 0.02 and 0.03 mg/l during the 2001-2002 monitoring period. Figure 4C shows arsenic concentration trend lines for 5 representative wells in the RBC GWMA.

In the Vashon-Maury Island (VMI) GWMA only 2 wells, VAS_w-04 and VAS_w-07, exceeded the MCL. Those wells had concentrations between 0.01 and 0.02 mg/l arsenic. The arsenic concentrations for five VMI wells are shown on Figure 4D.

Figure 5 is a graph showing arsenic concentrations plotted against well depth by GWMA . This graph was prepared to see if there is correlation between elevated arsenic concentrations and well depth. The graph shows a slight positive correlation between depth and concentration. The trend in the Issaquah Creek Valley and Redmond-Bear Creek data shows an increasing arsenic concentration with depth. East King County sites have greater concentrations overall and slight positive trend. Most of the GWMAs have wells less than 300 feet, Vashon-Maury Island (VMI) being the exception. The data from VMI show a bell shaped curve with the greatest arsenic values centered around 300 feet below land surface and concentrations decreasing toward shallower and deeper depths.

3.2.2 Nitrate

Nitrate occurs in groundwater in many areas of the United States. Nitrate (NO_3) has been studied extensively because of potential human health effects at concentrations above the MCL of 10 mg/l ($N0_3$ as N). There have been a few cases in the United States where nitrate concentrations above 10 mg/l have been linked to the occurrence of methemoglobinemia, or blue baby syndrome. This syndrome is very rare and is the result of nitrate affecting infant blood chemistry.

Nitrate has many natural and human sources in the environment. Nitrate is a component of most lawn and garden fertilizers. Because nitrate is very soluble in water, it can easily be leached into shallow groundwater in areas where fertilizer is commonly applied, such as gardens, farms, and golf courses. Nitrate is also a component of animal and human waste. Therefore, shallow groundwater is sometimes impacted by nitrate near household septic system drainfields and animal feedlots. Some plants, such as clover and alders, cause nitrogen to be fixed out of the atmosphere and thus enrich the soil and groundwater in nitrates. Nitrate is also commonly used as a preservative, and is present in smoked meats.

Because nitrate contamination of groundwater can be caused by many of man's activities, it is commonly used as a general indicator of groundwater quality. Groundwater unaffected by man's activities typically has nitrate concentrations less than 1 mg/l (N). Although there are no documented human health effects with nitrate concentrations less than 10 mg/l, many agencies use the concentration of 5 mg/l as a trigger for more intensive monitoring.

All four King County GWMAs have some wells with elevated nitrate concentrations, but only one well, EKC16, exceeded the 10 mg/l MCL for nitrate. EKC16 was tested for nitrate seven times during the 2001 – 2004 period and the only MCL exceedance was 11.3 mg/l detected in the December 2001 event. Subsequent tests in 2002, 2003, and 2004 measured concentrations ranging from 0.5 to 6.4 mg/l.

Figures 6A through 6D show nitrate concentrations at representative wells from each of the four GWMAs for the 2001 – 2004 period. A few of the wells, such as VAS_w-16a and RBC-21, have had declining nitrate concentrations for the period of record. Most of the wells have variable nitrate concentrations, but average nitrate concentrations have been fairly constant in the four GWMAs.

Figure 7 is a graph showing nitrate concentrations plotted against well depth. This graph was prepared to see if there is correlation between elevated nitrate concentrations and well depth. The nitrate concentrations appear to higher in the shallow wells, particularly wells less than fifty feet deep. Because nitrate contamination typically comes from sources near the ground surface, such as farm fields and septic system drainfields, shallow wells are more susceptible to nitrate contamination than deep wells.

3.2.3 Lead

Lead has been detected in groundwater from each of the four GWMAs. Like arsenic, lead is leached from rocks and minerals as groundwater moves through the subsurface. Unlike arsenic, the lead derived from leaching of rocks and minerals in King County is generally found at concentrations less than 0.005 mg/l in groundwater, well below the drinking water MCL (action level) of 0.015 mg/l.

Prior to the 2001 – 2004 monitoring period, lead was detected at concentrations above the MCL in several wells in the GWMAs. Several of those wells are still in the monitoring program, but they no longer produce groundwater with lead concentration above the MCL. Section 5 contains a discussion comparing 2001 – 2004 lead concentrations with historic water quality data.

There were only two detections of lead above the MCL in all four GWMAs during the 2001 – 2004 period. Both of these detections are a result of sampling error and as such are not representative of groundwater from these sites, ISS-10 & EKC06. These data are presented in Appendices C & D for completeness but this information should not be included when evaluating the potability of the water.

3.2.4 Sodium

Sodium is a metal that is found in groundwater at varying concentrations. The EPA has a guidance level of 20 mg/L for individuals that have low sodium diets. Sodium content of water is relatively unimportant for healthy persons because the intake of sodium from other food and drink is so much greater. Persons following a low sodium diet because of hypertension or kidney or cardiovascular disease, however, should be concerned with the elevated level of sodium.

Each GWMA had 2 or more sites with sodium concentrations exceeding this level, Appendices A – D. Site RBC-12 had the highest concentration of sodium at 114 mg/L.

3.2.5 Organic Compounds

The King County groundwater monitoring program included a comprehensive list of organic chemical target analytes that are divided into three general groups, volatile organic compounds, semivolatile organic compounds (also called base/neutral/acid extractable organic compounds), and organic-chlorinated herbicides. The organic analytes are listed on Table 3. Almost all of the organic chemicals being tested are manufactured by man and therefore do not naturally occur in groundwater. MCLs are listed on Table 3 for those compounds where an MCL has been assigned. In general, MCLs have been assigned for those organic analytes that have been commonly detected in groundwater impacted by industrial or agricultural activities in other areas of the country.

There have been very few detections of the organic analytes in the four GWMAs during the 2001 – 2004 monitoring period. The organic analytes were only tested in the four GWMAs once. The results from this sampling were similar to previous monitoring, see section 5.1 for more details. Because there were so few detections and to reduce overall program costs, the organics testing was not continued in other sampling events.

The only organic analytes that were detected in all four of the GWMAs were the phthalates. The analyte list includes six phthalate compounds. Bis(2-ethylhexyl)phthalate (Bis2EHP) was the phthalate most commonly detected. Bis2EHP is the only phthalate that has been assigned a drinking water MCL, which is 0.006 mg/l. Phthalates are semivolatile organic compounds used primarily as plasticizers in the manufacture of various types of plastic. Phthalates are known to leach into water from certain types of plastic containers, and have been detected in bottled water that is in plastic containers. However, phthalates are rarely present in high concentrations, and Bis2EHP is generally not detected at concentrations above the MCL.

After initial organic sampling, King County Environmental Lab discovered that the sampling technique used to collect the organic samples probably contaminated results for phthalates. Re-sampling of a few sites with elevated concentrations yielded data confirming a sampling bias. These data from VAS_w-14, EKC16, and EKC19. are designated by an R qualifier (rejected data), see Appendices A and D. The analytical results presented in the appendices are presented as received from the laboratory, so the units for concentrations of organic compounds are micrograms per liter (µg/l). The concentrations have been converted to mg/l in the text for comparison to the MCLs.

Three other semivolatile organic compounds (benzoic acid, phenol, and phenanthrene) were detected, but at concentrations well below any known potential health effects. Benzoic acid was reported in four samples; the maximum estimated concentration of benzoic acid in the data set is 0.00032 mg/l (in well VAS_w-21). Benzoic acid is a man-made compound commonly used as a food and beverage additive. Phenol was reported in nine samples with a maximum concentration of 0.000118 mg/l (in VAS_s-02). Phenanthrene was reported in one sample (in VAS_w-13) at an estimated concentration of 0.0000065 mg/l.

There were only three detections of volatile organic compounds. Tetrachloroethene was detected in RBC well RBC-37 at concentrations of 0.00011 and 0.00036 mg/l in December 2001. These concentrations are well below the tetrachloroethene MCL of 0.005 mg/l. Tetrachloroethene is a chlorinated solvent used as a degreaser. Chloroform was also detected in well RBC-37 at a concentration of 0.00036 mg/l, well below the MCL of 0.08 mg/l. Chloroform is an industrial chemical, and sometime occurs as a by-product of water chlorination. Well RBC-37 has not been resampled due to the detections being confirmed by other analyses in RBC-37. The tetrachloroethene was from a nearby dry cleaner release. Trichloroethylene was detected at a concentration of 0.00012 mg/l in the sample from well ISS-06, much less than the MCL of 0.005 mg/l. Well ISS-06 has not been resampled due to detection being confirmed by earlier sampling at this location.

The only chlorinated-organic herbicide detected in all four GWMAs was Atrazine in RBC well RBC-30 at a concentration of 0.000051 mg/l, much lower than the Atrazine MCL of 0.003 mg/l. The well has not been resampled due to the knowledge that this location had a storage area near the well that contained herbicides including Atrazine.

3.2.6 Bacteria

Coliform bacteria tests were conducted on groundwater samples during the first two sampling events. Additional sampling of the coliform bacteria beyond the initial assessment was done at selected sites when requested by the well owner. Two types of bacteria tests were conducted, total and fecal coliform. Coliform bacteria are very common in the environment, and only certain types of coliform bacteria, such as fecal coliform, are considered to have potential human health impacts. Fecal and other coliforms in groundwater are more often indicators of a poorly sealed well head via seepage from surface soil contamination.

The drinking water MCL for total coliform bacteria requires that no more than 5% of routine samples collected in a single month from a single water supply have a positive total coliform result. The presence of fecal coliform indicates possible contamination from human or animal waste products. The presence of fecal coliform in groundwater is generally considered to be an indicator of a nearby septic drainfield or animal feedlot.

During the 2001 – 2004 monitoring program three of the GWMAs had positive total coliform detections. Each of the GWMAs had from one to three wells with positive total coliform detections, Appendices A – D. There was one detection of fecal coliform in well EKC06. All of the wells with positive total coliform detections were resampled, and none of the wells had positive detections in the subsequent events.

3.2.7 Secondary Drinking Water Standards

Secondary drinking water standards were established because of the undesirable impacts of certain naturally occurring metals and other compounds. Table 4 shows several analytes that have secondary MCLs, such as copper, iron, manganese, sulfate, and total dissolved solids. The aesthetic impacts resulting from the presence of these materials in groundwater include, disagreeable taste (chloride), foul odor (sulfate), staining of clothes and plumbing fixtures (iron and manganese). The secondary MCLs were not established because of potential human health effects of these analytes.

Iron and manganese were found at concentrations above the secondary MCLs in wells located in all four of the GWMAs, Appendices A – D. These metals are commonly found at concentrations exceeding the secondary MCLs in groundwater west of the Cascade Mountains. This condition is not unique to King County. The iron and manganese in groundwater are derived by natural leaching of the metals from rocks and soil minerals. The iron and manganese concentrations can be reduced below MCLs with the use of commercially available water treatment systems that are installed in the well plumbing system, as generally shown on Figure 3.

4.0. WATER QUANTITY RESULTS

4.1 Water Level Monitoring Program

As shown on Table 1, groundwater depth measurements have been made at 57 of the 68 monitoring wells during the King County program. An additional 24 sites on Vashon-Maury Island have been monitored as part of a pilot volunteer network, see section 4.2. The purpose of this type of monitoring is to compile a groundwater level database for analysis of long term water level trends. The wells are completed in all of the primary aquifers in each of the GWMAs.

Prior to sampling each well, the electric indicator probe is lowered on a cable into the well casing. Before lowering the probe into the well, the probe tip is washed to prevent contamination of the well. When the indicator probe reaches the water table, the meter light goes on or an alarm sounds. The depth to water is then determined from the depths marked on the cable. The water level data are recorded in the field notes and later entered into the database.

4.2 Volunteer water level monitors

Vashon-Maury Island GWMA has a unique volunteer water level monitoring program. In 2001, a pilot program with twenty-six volunteers started to take monthly water level measurements at their wells, Figure 9. Two of these sites are part of the water quality sampling program on VMI. Equipment and training was provided by King County GWPP staff. The measurements are made on a voluntary basis by the well owners and the data are provided to the DNRP. Initial efforts were very positive however participation within the program dropped after the first 2 years. Currently, as of 2005, 5 volunteers are still monitoring their wells monthly, see Appendix D, Table D-6, water level data table.

4.3 Results

There are some limitations to the water level data being generated in the program. These limitations are the frequency of measurements, unknown pump usage prior to measurements and areal distribution within the GWMAs. Water level measurements from East King County and Vashon-Maury Island management areas covered the entire 2001 – 2004 monitoring period, but the Issaquah Creek and Redmond Bear Creek water level measurements did not extend past the 2002 monitoring events. Only VMI has locations recording water level measurements on a monthly basis. The other areas have less frequent measurements ranging from just one measurement to quarterly measurements during the 2001 – 2004 monitoring period.

A few of the sites monitored have a long recovery time for the water level to rise to static (non-pumping) conditions after the well pump has shut off. By having limited knowledge about the prior pump history, it is possible to record water level fluctuations related to pumping effects and not to any regional water level changes to the aquifer.

The distribution of wells being monitored in each GWMA is generally useful for assessing regional trends, but the data in some areas reflect local topographic effects on the water levels, as in EKC. However, even with these limitations, the data are useful for evaluating water level trends.

Groundwater depth data for all four GWMAs are plotted on Figures 8A, 8B, 8C, and 8D. Since the East King County and Vashon-Maury Island wells include four years of data, those graphs are the most useful for evaluating trends. The water level plots for EKC and VMI indicate that groundwater depths in the aquifers were generally stable during the period of record, with no significant declines.

Daily total precipitation data, in inches, are also plotted at the top of each graph. There is a correlation between increased rainfall and water table rise for the shallowest wells plotted on Figures 8A and 8D. This rapid response to aquifer recharge from the infiltration of precipitation is commonly recorded in the shallow aquifers of western Washington.

5.0. DISCUSSION

One of the Groundwater Protection Program goals is assess the state of the groundwater within King County. This monitoring program (2001 – 2004) provides an overview of the condition of the groundwater quality and quantity in each of the groundwater management areas. Overall, the condition of the water quality of the groundwater in King County is very good, see Tables 4-7 and Appendices A – D.

5.1 East King County GWMA

Fifteen sites have been monitored for water quality and 14 of these sites have at least one water level measurement, Figure 2A and Table 1. Overall the water quality is good and the water level trends from selected wells appeared to be unchanged, Figure 8A and Table 4. Arsenic is the one parameter that appears to have the greatest effect on water quality within this area. Eight of the 15 sites have elevated arsenic concentrations reported one or more times. Most of the highest arsenic concentrations across the entire county were obtained from East King County sites, Appendix A.

East King County groundwater likely has a higher percentage of wells with elevated arsenic because arsenic is being leached at higher concentrations from the area rocks and soil minerals. The depth to bedrock is shallower in this region of the county relative to the other GWMAs and thus drinking water wells, even at the same depth, are closer to the bedrock. This closer proximity of the wells to the source may be the source of the higher arsenic concentrations for East King County.

Three additional parameters (iron, manganese, and nitrate) have MCLs that were exceeded one or more times during this monitoring program. The guidance concentration for sodium was also exceeded in samples from several wells. The range of sodium concentrations for this area extends only up to about 51.5 mg/l, the lowest maximum value in the four GWMAs. Table 4 lists the number of sites that exceeded these parameters. The one lead exceedance was determined to be a sampling error not representative of the groundwater quality.

5.2 Issaquah Creek Valley GWMA

Fifteen sites have been monitored for water quality and 11 of these sites have at least one water level measurement, Figure 2B and Table 1. Overall the water quality is very good to excellent and the water level trends from selected wells appeared to be seasonal, Figure 8B and Table 5. This area had the fewest number of exceedances of the MCLs, Table 5. Iron and manganese are the most frequent parameters of concern, Appendix B. As stated in Section 3.2.7, these metals are common within the groundwater of this region and have secondary drinking water standards.

The guidance concentration for sodium was exceeded in several samples. Table 5 lists the number of samples that exceeded the guidance level. The one lead exceedance was determined to be a sampling error not representative of the groundwater quality.

5.3 Redmond-Bear Creek Valley GWMA

Sixteen sites have been monitored for water quality and all of these sites have at least one water level measurement, Figure 2C and Table 1. Overall the water quality is very good and the water level trends from selected wells appeared to be unchanged, Figure 8C and Table 6. This area has one site (RBC-05) that exceeds the new MCL for arsenic, Appendix C . Iron and manganese are the most frequent parameters of concern for this area, Table 6. As stated in Section 3.2.7, these metals are common within the groundwater of this region and have secondary drinking water standards. The guidance concentration for sodium was exceeded in several samples. Table 6 lists the number of samples that exceeded the guidance level.

5.4 Vashon-Maury Island GWMA

Twenty-two sites have been monitored for water quality and 16 of these sites have at least one water level measurement, Figure 2D and Table 1. Twenty-four additional sites have also been monitored for water level data only, Table 1 and Figure 9. Overall the water quality is good and the water level trends from selected wells appeared to be unchanged, Figure 8D and Table 7.

This area has two sites (VAS_w-04 and VAS_w-07) that consistently exceed the new MCL for arsenic, Appendix D. Iron and manganese are the parameters that most frequently exceed the MCLs, Table 7. As stated in Section 3.2.7, these metals are common in the groundwater of this region and have secondary drinking water standards.

The guidance concentration for sodium was exceeded in several samples. Table 5 lists the number of samples that exceeded the guidance level. The range of sodium concentrations for this area extends only up to about 58.6 mg/l, one of the lowest values of the GWMAs.

5.5 Comparison to Groundwater Management Plan (1989 – 1995) Results

More than a decade has passed since intensive groundwater monitoring was initiated in the four GWMAs. A larger version of the current monitoring program in the four GWMAs began during the period 1989 through 1995. The groundwater management plans for each GWMA require the evaluation of long term water quality trends. Section 3 described the 2001 – 2004 water quality data for arsenic, nitrate, lead, and iron. Nitrate, lead and iron concentrations have historically been elevated or exceeded MCLs in all of the GWMAs. Arsenic concentrations will exceed MCLs according to standards that become applicable in 2006. These target analytes are considered indicator parameters for the analysis of long term water quality trends in King County.

5.5.1 Arsenic

The arsenic concentrations measured in each of the four GWMAs during the 1989-1995 period were compared with the concentrations in the 2001 – 2004 samples. In general the arsenic concentrations are stable, with little or no increase or decrease over the period of record. This is illustrated on Figure 10, which contains all of the arsenic groundwater data for the East King County GWMA. Many of the EKC wells exceeded the 2006 arsenic MCL throughout the period of record, with little apparent change. Since the arsenic is thought to be derived from natural groundwater leaching from rocks and minerals, we do not expect to see concentrations decline in the foreseeable future.

5.5.2 Nitrate

All of the nitrate data for all four of the GWMAs is plotted on Figure 11. In general it appears that nitrate concentrations have increased slightly over the monitoring period in all four GWMAs. Although very few individual wells have exceeded the 10 mg/l drinking water MCL, the general increase in nitrate concentrations is of concern because future development in these areas is likely to exacerbate this trend. The groundwater management plans for all four GWMAs recognize that nitrate concentrations in groundwater are directly impacted by housing density, fertilizer application practices, and other effects of land uses.

5.5.3 Lead

All of the lead data for the four GWMAs is plotted on Figure 12. During the 1990 monitoring period several of the wells exceeded the drinking water MCL. Only two of the wells exceeded the MCL in the 2001 – 2004 period, as described in Section 3.2.3. The data indicate a significant decline in the number of wells with lead concentrations exceeding the MCL. This is believed to be largely due to modifications made to remove lead-based solder from the plumbing systems where elevated lead concentrations had been detected during the 1989-1993 period.

5.5.4 Iron

All of the iron data for the four GWMAs is plotted on Figure 13. The data indicate that iron concentrations in all four GWMAs are stable. This is expected, since the iron is naturally derived from dissolution of rocks and minerals. It is expected that iron concentrations will continue to exceed the MCL in many wells in the four GWMAs for the foreseeable future.

5.6 Long Term Monitoring Programs

Additional monitoring and/or continued monitoring at selected sites is prudent to determine long-term trends. The USGS published a report about the importance of long-term groundwater monitoring, USGS circular 1217. The following is an excerpt from this report:

> Measurements of water levels in wells provide the most fundamental indicator of the status of this resource and are critical to meaningful evaluations of the quantity and quality of groundwater and its interaction with surface water.

This type of data analysis is most relevant in assessing water level/table trends. Having frequent water level data (such as quarterly or monthly data) allows for better assessment of water table fluctuations. Determining regional water tables allows for greater understanding of the entire watershed flow dynamics. Surface water/groundwater interaction is an important component of this analysis.

5.6.1 Rationale for modifications

King County has conducted a groundwater quality monitoring program in the GWMAs for the last four years. The wells selected have been fairly representative of the major aquifers and reasonably representative from a geographic perspective. The monitoring has revealed several significant water quality issues in the GWMAs that should be further evaluated and monitored. These include increasing nitrate concentrations in some areas, and fairly widespread exceedance in some areas of the 2006 arsenic MCL. On the positive side, the monitoring has also shown that there have been no detections or only trace concentrations detected of the majority of analytes tested in the program. We can reasonable conclude that there are currently no widespread water quality issues related to 99% of the analytes being currently tested. Therefore it makes sense to expand the monitoring program to additional wells targeting only indicator parameters, such as nitrate, arsenic, and selected solvents.

Water level measurements should be continued in the all of the wells in the expanded network. Quarterly water level measurements should be made by cooperating well owners. This would allow the monitoring program to be more sensitive to subregional groundwater overdraft conditions that could occur if the current drought period continues. Expansion of the monitoring well network would have the added benefit of improving the sensitivity of the water level monitoring program.

5.6.2 Plan to Reduce Target Analytes and Expand Well Monitoring Network

There are currently 68 water quality monitoring wells covering the four GWMAs. Additional monitoring wells could be selected in each area to roughly double the number of wells in the network. The additional labor costs associated with selecting the wells, obtaining access agreements, and sampling; would be offset by the reduced laboratory costs resulting from testing only for indicator analytes.

The county should consider using a tiered testing program in the GWMAs. Under a tiered approach, indicator analytes, such as nitrate, are tested in all wells. Trigger concentrations would be set for some analytes, which if exceeded, would require more expanded testing. For other analytes, such as TCE, a detection at any concentration would trigger expanded testing, as described below.

Nitrate is a very soluble conservative contaminant that is generally indicative of a number of domestic sewage and agricultural sources. Therefore it should be used as an indicator analyte at all wells. Arsenic is a potentially serious contaminant that requires further definition in all of the GWMAs. The EPA has shown that certain chlorinated solvents, such as TCE and PCE are excellent indicators of contamination from various industrial sources. EPA studies have shown that TCE or PCE are present in the majority of sites where industrial activities have resulted in groundwater contamination. Therefore we would propose to use nitrate, arsenic, and selected chlorinated solvents as target indicator analytes in the expanded monitoring program.

For new wells in the network, if nitrate is detected above 5 mg/l, the well should be resampled and tested for other analytes associated with nitrate, such as herbicides and pesticides. If PCE or TCE are detected in a new well, the full suite of VOCs and semi-VOCs should be tested in the well. Otherwise, groundwater from each well would only be tested for the indicator analytes.

Using this monitoring approach the county will have a more comprehensive well network that is testing for the key problem analytes.

6.0. REFERENCES

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