GSI Water Solutions, Inc.

Technical Memorandum

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EXP: 4/30/13

To: Jim Harper, PE, Brown and Caldwell, Inc.
Angela Wieland, PE, Brown and Caldwell, Inc.

From: Matt Kohlbecker, RG, GSI Water Solutions, Inc.
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Date: January 16, 2013

Re: **Unsaturated Zone Groundwater Protectiveness Demonstration**
City of Milwaukie, Oregon

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1. Introduction

An Underground Injection Control (UIC) is any facility designed for the subsurface infiltration of fluids. The City of Milwaukie (City), Oregon, uses 196 (recorded) UIC devices to manage stormwater from public rights-of-way (ROW). The locations of the City's UICs are shown in Figure 1. The City's UICs provide benefit to the local watershed by maintaining aquifer recharge in the urban environment. In addition, they are protective of sensitive aquatic receptors by providing an alternative to direct discharge to surface water. UICs are regulated by the Oregon Department of Environmental Quality (DEQ). Because the City's UICs infiltrate only stormwater from public ROWs, DEQ considers them to be Class V injection systems under Oregon Administrative Rules (OAR) 340-044-0011(5)(d).

The City has retained Brown and Caldwell to update its 2004 Stormwater Master Plan (SMP). An objective of the SMP is to identify Capital Improvement Projects (CIP) to retrofit UICs or manage flow from UICs that are removed from service by decommissioning. UICs that require retrofit or decommissioning will be identified on the basis of conditions of a UIC Water Pollution Control Facilities (WPCF) permit that the City likely will receive in late 2013.

This technical memorandum presents an evaluation of whether City UICs will require retrofit or decommissioning based on conditions of the July 2012 draft *Water Pollution Control Facilities Permit for Class V Stormwater Underground Injection Control Systems* (DEQ, 2012a) (draft July 2012 UIC WPCF permit template). The first step in the evaluation is to conduct a system-wide assessment that identifies "at-risk" UICs that would potentially need retrofit or decommissioning because they either 1) discharge directly to groundwater or 2) are located within permit-specified setbacks of water wells. The second step of the evaluation is to conduct

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an unsaturated zone Groundwater Protectiveness Demonstration (GWPD). The GWPD is used to determine which of the "at-risk" UICs identified during the system-wide assessment would need to be decommissioned due to inadequate vertical separation distance from the bottom of the UIC to groundwater.

1.1 Objectives

The objectives of this technical memorandum are:

- Present the preliminary system-wide assessment based on water well location information, as provided by the City and UIC data from the City's 2005 UIC Stormwater Management Plan (HDR, 2005).
- Present a GWPD model, and document model applications to:
    - Address UICs that discharge directly to groundwater and/or were identified within setbacks to water wells as a part of the preliminary system-wide assessment (as described in Condition 6(b)(i) of Schedule A in the draft July 2012 UIC WPCF permit template).
    - Develop Alternate Action Levels to support stormwater discharge monitoring under the City's UIC WPCF permit.
- Based on the results of the GWPD, identify UICs for retrofit or decommissioning as a part of future CIPs.

The main text of the technical memorandum provides an overview of the UIC system-wide assessment and unsaturated zone GWPD model. Additional technical details are provided in Attachment A (UIC system-wide assessment), Attachment B (technical documentation for the unsaturated zone GWPD model), and Attachment C (the unsaturated zone GWPD model).

1.2 Technical Memorandum Organization

This technical memorandum is organized as follows:

- **Section 1: Introduction**. Discusses the City's UIC system and outlines the technical memorandum's objectives.
- **Section 2: UIC Conceptual Model.** Provides information about City UIC facilities and conceptual model for City UIC facilities.
- **Section 3: Preliminary System-Wide Assessment.** Identifies UICs within water well setbacks (Section 3.1), UICs that discharge directly to groundwater (Section 3.2), and actions required to address these UICs (Section 3.3).
- **Section 4: GWPD Application.** Provides background related to the different types of GWPDs and summarizes how they are used to demonstrate groundwater protectiveness.
- **Section 5: Unsaturated Zone GWPD Model**. Documents the unsaturated zone GWPD model used for the City, including model input parameters (Section 5.1) and model results (Section 5.2).
- **Section 6: Conclusions and Recommendations**

- **References.**

2. UIC Conceptual Model

A typical UIC facility in the City is comprised of a catch basin that collects stormwater runoff from the public ROW; piping that conveys the stormwater from the catch basin to the UIC; and the UIC itself that infiltrates stormwater to the subsurface. Occasionally, a sedimentation manhole (i.e., a solid concrete cylinder) is installed between the catch basin and UIC to allow for sediment in stormwater to settle before entering the UIC and to prevent floatables (e.g., trash and debris, oil and grease) from flowing into the UIC. UICs in the City are typically 15- to 30-foot-deep, 4-foot-diameter cylindrical structures constructed of concrete. Rectangular openings (perforations) in the concrete walls of a UIC allow stormwater to infiltrate from the sides of the UIC, and many of the UICs are completed with an open bottom to allow stormwater to infiltrate from the bottom of the UIC.

The conceptual site model for stormwater infiltration from a UIC and pollutant fate and transport after the water leaves the UIC is shown schematically in Figure 2. As shown in Figure 2, stormwater discharges into the UIC, infiltrates through the unsaturated zone, and recharges groundwater. Infiltration through the unsaturated zone likely occurs under near-saturated conditions because of the near-constant infiltration of water during the rainy season. Before entering the unsaturated zone, large-size particulate matter (which pollutants may be sorbed to) falls out of suspension into the bottom of the UIC. During transport through the unsaturated zone, pollutant concentrations attenuate because of degradation, dispersion, volatilization, and retardation. Therefore, pollutant concentrations in unsaturated zone porewater beneath the UIC decrease as the water filters downward through the unsaturated zone to the water table.

3. Preliminary System-Wide Assessment

This section presents a preliminary system-wide assessment of the City's UICs. A system-wide assessment is an inventory of the physical characteristics of a City's UICs. Condition 1 of Schedule B in the draft July 2012 UIC WPCF permit template stipulates that the system-wide assessment must include:

1. An inventory of all UICs that receive stormwater or other fluids and their locations by latitude and longitude in decimal degrees.
2. An estimate of vehicle trips per day for the area(s) drained by the UICs.
3. An inventory of all UICs that discharge directly to groundwater.
4. An inventory of all UICs within 500 feet of any water well and/or within the 2-year time-of-travel of a public water well.
5. An inventory of all UICs that are prohibited by OAR 340-044-0015(2).
6. An inventory of all industrial and commercial properties with activities that have the potential to discharge to UICs that the City owns or operates.

The City developed a summary of its UIC system in 2005 as a part of the City's UIC Stormwater Management Plan (HDR, 2005). The 2005 system summary contains most of the information required by the July 2012 draft permit template for a system-wide assessment, but prior to the City submitting their system-wide assessment (in conjunction with receipt of their permit) the following information would be needed:

(1) Identification of additional UICs within setbacks to water wells based on water well location information collected by the City since 2005 (Item 4 above), and

(2) Updates to the inventory to reflect new vertical separation distance requirements in the draft July 2012 UIC WPCF permit template (Item 3 above).

In this technical memorandum, the following sections provide updated information to the HDR (2005) system summary by identifying UICs within water well setbacks (Section 3.1) and UICs that discharge directly to groundwater (Section 3.2), and providing recommendations for corrective action (Section 3.3).

3.1 UICs Within Water Well Setbacks

This section discusses the methods used to identify UICs within permit-specified setbacks to water wells (i.e., 500 feet or the 2-year time-of-travel). As explained in the *Permit Template Evaluation Report – Class V UIC Municipal and Industrial/Commercial Stormwater Water Pollution Control Facilities Permit* (DEQ, 2012b) (which accompanies the draft July 2012 UIC WPCF permit template), water wells include domestic, irrigation, industrial, and public water wells used for water supply. If a jurisdiction can demonstrate that it is unlikely that irrigation or industrial wells will be used for domestic or municipal water supply, then they can be removed from consideration as water wells.

Irrigation, industrial, domestic, and municipal water wells within the City are identified in Table 1 and shown in the left panel of Figure 3.

Identification of UICs within water well setbacks is based on the following water well location information provided by the City:

- Locations of City municipal wells (Well Numbers 2 through 8) by latitude and longitude (personal communication, 2012a).
- Locations of water wells from the Oregon Water Resources Department (OWRD) water rights database (personal communication, 2012b). These wells were located to the nearest quarter quarter section (which has an accuracy of $^+/_-$ 1,320 feet) or using the legal description in the water right (if provided).
- Locations of private water wells provided by the City (personal communication, 2012c). The private wells are located using the address on driller logs from the online OWRD well log query, and are accurate to the property on which the well is located.

Note that the water well inventory in Table 1 and Figure 3 may be is incomplete because it likely omits several water well locations in the City that could not be accurately located. Additional data sources would need to be consulted to ensure a complete inventory of water well locations. Data sources would include the online OWRD well log query (i.e., for wells without addresses), DEQ well location studies related to the solvent plume that has impacted City municipal wells, and City water service connection records.

At this time, thirty-three UICs are either within 500 feet of a water well or within the 2-year time-of-travel of a public water well. These "at-risk" UICs are shown in the left panel of Figure 3 and are listed in Table 2 and Attachment A.

3.2 UICs That Discharge Directly to Groundwater

UICs that discharge directly to groundwater ("wet feet" UICs) were identified on the basis of the U.S. Geological Survey (USGS; USGS, 2008) depth to groundwater study for the Portland Basin and UIC depths measured as a part of the *UIC Stormwater Management Plan* (HDR, 2005). Wet feet UICs were identified by the following formula:

$$SD = \left(DTW_{USGS} - \frac{\Delta s_{USGS}}{2}\right) - d_{UIC} \tag{3.1}$$

Where:

SD	=	Vertical separation distance between the bottom of the UIC and seasonal high groundwater (feet)
DTW_{USGS}	=	Average depth to water beneath a UIC from USGS (2008) (feet)
Δs_{USGS}	=	Seasonal fluctuation in the water table from USGS (2008) (5.9 feet), based on a statistical analysis of seasonal groundwater level fluctuations in the Portland Basin for the Unconsolidated Sedimentary Aquifer (the hydrogeologic unit where most City UICs are located).
d_{UIC}	=	Depth of the UIC measured by HDR (2005) (feet)

UICs with a negative separation distance (*SD*) are considered to be wet feet UICs. Two wet feet UICs (UIC ID Nos. 24027 and 44003) were identified using Equation 3.1, and are shown in the right panel of Figure 3. Additional information about the wet feet UICs is provided in Attachment A (see highlighted rows).

3.3 Actions for UICs Within Water Well Setbacks and UICs That Discharge Directly to Groundwater

This section discusses actions for UICs that discharge directly to groundwater and for UICs within setbacks to water wells, based on the draft July 2012 UIC WPCF permit template.

Action for UICs That Discharge Directly to Groundwater

Direct discharge to groundwater is not prohibited in the draft July 2012 UIC WPCF permit template. However, additional action is required for UICs that discharge directly to groundwater if the UIC is within the setback to a water well (see Condition 3 of Schedule B of the permit template).

Neither of the two City UICs that discharge directly to groundwater is located within a setback to a water well in Table 1, so no action is required at this time. However, if additional water wells are identified when the system-wide assessment is finalized, and either of the two wet-feet UICs is located within setbacks to the newly identified wells, then the City will be required to show that the UICs will not affect groundwater users (by Condition 3 of Schedule B of the draft July 2012 UIC WPCF permit template). Alternatively, the permitee may decommission the UICs or structurally retrofit the UICs so that the direct discharge to groundwater is eliminated, thus eliminating the potential for required future action if additional wells are identified.

Action for UICs Within Water Well Setbacks

Under the draft July 2012 UIC WPCF permit template, it is not a permit violation for existing injection systems to be within the horizontal setbacks from water wells; however, the UICs must be addressed by one of the following actions within one year of discovery:

- Conduct a protectiveness demonstration to show that the existing UIC does not impair groundwater quality or supply (Condition 6(b)(i) of Schedule A).
- Retrofit or implement a passive, structural, and/or technological control to reduce or eliminate pollutants to the UIC (Condition 6(b)(ii) of Schedule A).
- Close the UIC (Condition 6(b)(iii) of Schedule A).

The GWPD summarized in this technical memorandum will satisfy Condition 6(b)(i) of Schedule A, thus eliminating the need to conduct any additional activities to address UICs within specified setbacks from identified wells at this time.

4. GWPD Application

There are two approaches for demonstrating groundwater protectiveness using a model. Both approaches simulate attenuation of stormwater pollutants in the subsurface (i.e., after infiltration from a UIC), but differ based on whether they simulate pollutant attenuation during vertical transport in unsaturated soils above the water table (unsaturated zone GWPD) or pollutant attenuation during horizontal transport in saturated soils below the water table (saturated zone GWPD). Additional detail related to the two types of GWPDs is provided below:

- **Unsaturated Zone GWPD**. Unsaturated zone GWPDs are based on modeling pollutant fate and transport *vertically* through the *unsaturated* soils beneath a UIC. Groundwater protectiveness is demonstrated by showing that the pollutants attenuate to below background levels before reaching the groundwater table, and, therefore, that the pollutants do not impair groundwater quality.

- **Saturated Zone GWPD.** A saturated zone GWPD consists of modeling *horizontal* pollutant fate and transport through *saturated* soils. The model is used to demonstrate that that the UIC does not adversely impact groundwater users by delineating the "area where waste or material that could become waste if released to the environment, is located or has been located" [OAR 340-040-0010(19)]. In the context of stormwater infiltration from a UIC, this area is the location where groundwater contains stormwater pollutants above background levels (i.e., which is considered to be the method reporting limit [MRL] for non-metals).

The City chose an unsaturated zone GWPD to demonstrate groundwater protectiveness because almost all City UICs have a significant thickness of unsaturated soils between the bottom of the UIC and groundwater table to attenuate pollutant concentrations.

5. Unsaturated Zone GWPD Model

This section summarizes the results of an unsaturated zone GWPD for UICs within water well setbacks that were identified as a part of the system-wide assessment (Section 3), and presents Alternate Action Levels for the City's UIC WPCF permit. The unsaturated zone GWPD model is based on a conservative, analytical pollutant fate and transport equation that simulates one-dimensional pollutant attenuation by dispersion, biodegradation, and retardation. The model output is pollutant concentrations over time and distance based on user-provided input parameters (soil properties, pollutant properties, and organic carbon content of the subsurface). The unsaturated zone GWPD model was used to demonstrate protectiveness and develop Alternate Action Levels:

- **Protectiveness Demonstration.** Protectiveness is demonstrated by showing the pollutant concentrations are attenuated to zero (i.e., below the MRL) before reaching the water table. Pollutant fate and transport are simulated for organic pollutants pentachlorophenol (PCP); di(2-ethylhexyl)phthalate (DEHP); and benzo(a)pyrene; and lead. These pollutants are among the most mobile, toxic, and environmentally persistent in their respective chemical classes (GSI, 2008). They will also be monitored under the City's UIC WPCF permit, and are the most likely pollutants in their respective chemical classes to exceed regulatory standards (Kennedy/Jenks, 2009).

- **Alternate Action Levels.** The draft July 2012 UIC WPCF permit template establishes Action Levels for pollutants in stormwater. Based on information from DEQ (B. Mason, personal communication, October 5, 2012), monitoring of the following pollutants will be required under municipal UIC WPCF permits: benzo(a)pyrene, DEHP, PCP, antimony, lead, zinc, and copper. Action Levels will be established for each pollutant in the City's UIC WPCF permit. Exceedance of an Action Level is not a permit violation. However, if a pollutant concentration exceeds an Action Level, then corrective action is required in accordance with Conditions 3 and 4 of Schedule A. The City is permitted to replace the Action Levels in the draft permit with Alternate Action Levels based on a GWPD model (Condition 2, Schedule A). Alternate Action Levels are developed for zinc, copper, antimony, and DEHP because the existing Action Levels in the draft July 2012 UIC WPCF permit template for these pollutants have not been adjusted on the basis of previous GWPDs (other Table 1 pollutants, lead, benzo(a)pyrene, and PCP, already have been adjusted upward based on other municipalities' unsaturated zone GWPDs).

The following section provides an overview of unsaturated zone GWPD model input parameters (Section 5.1) and results (Section 5.2). Detailed technical documentation for input parameters, the governing equations, and conservative assumptions in the unsaturated zone GWPD model are provided in Attachment B.

5.1 Input Parameters

Pollutant attenuation in subsurface soils depends on the following variables: (1) soil properties, (2) organic carbon content of the subsurface, and (3) pollutant properties. These variables are input parameters for the unsaturated zone GWPD model, and are based on local geologic conditions and stormwater chemistry in the City. The input parameters are varied to evaluate two scenarios for pollutant fate and transport: (1) the average scenario, which is represented by the central tendency or expected mean value of the input parameter, and (2) the reasonable maximum scenario, which is represented by the worst case, upper bound of the input parameter that potentially could occur. The following sections summarize the input parameters used in the unsaturated zone GWPD model for the average and reasonable maximum scenarios.

Soil Properties

Soil properties input into the unsaturated zone GWPD model are based on surficial geology in the Milwaukie vicinity. A surficial geology map of the City was obtained from the Oregon Department of Geology and Mineral Industries (DOGAMI), Oregon Geologic Data Compilation (DOGAMI, 2012), and is provided in Figure 4. Shallow geology in the City is composed of the catastrophic flood deposits of the Missoula Floods. All but one of the City's UICs (44003) are located in the fine-grained facies of the Missoula Flood Deposits (Qff), which are coarse sand to silt deposited by ponded floodwaters (Madin, 1990). The UIC that is not located in the fine-grained facies of the Qff discharges directly to groundwater, and is not included in the unsaturated zone GWPD model. Therefore, input parameters for the unsaturated zone GWPD model are based on soil properties in the Qff.

Soil properties used for the average and reasonable maximum scenarios of the unsaturated zone GWPD model are summarized in Table 3. Porosity, bulk density, and the dispersion coefficient were taken from literature references based on the properties of the Qff. Average linear pore water velocity was estimated from 11 infiltration tests conducted by the City at City UICs in the Qff. The City conducted infiltration tests at the locations shown in Figure 4. Technical documentation for using infiltration tests to calculate average linear pore water velocity is provided in Attachment B.

Organic Carbon Content of the Subsurface

The organic carbon content of the subsurface that is input into the unsaturated zone GWPD model (i.e., f_{oc}, a dimensionless measure of organic carbon content in a soil [grams of carbon per grams of soil]) is based on carbon loading of soil during stormwater infiltration. Organic carbon concentrations in stormwater vary during the year, reaching the highest levels in the fall during leaf drop and the lowest levels during the winter. The total organic carbon (TOC) concentration in stormwater was calculated from more than 100 stormwater samples collected at different times of the year in Milwaukie and nearby jurisdictions. Specifically, TOC data include samples from 61 UICs in Gresham (collected by the City of Gresham), 15 UICs in Clackamas County (collected by Clackamas County Water Environment Services), 12 UICs in Portland (collected by the City of Portland Bureau of Environmental Services), and 15 UICs in Milwaukie (collected by City staff). The unsaturated zone GWPD model uses an f_{oc} of 0.0208 g_{carbon}/g_{soil} for the average scenario (based on mean TOC concentration in stormwater) and an f_{oc} 0.0024 g_{carbon}/g_{soil} for the reasonable maximum scenario (based on minimum TOC concentrations observed in stormwater). Technical documentation for calculating f_{oc} based on filtering of particulate matter in stormwater is provided in Section 2.2 of Attachment B.

Pollutant Properties

Pollutant properties used for the average and reasonable maximum scenarios of the unsaturated zone GWPD model are summarized in Table 4. Pollutant properties for organic chemicals (i.e., PCP, DEHP and benzo(a)pyrene) are based on literature references, and pollutant properties for metals (i.e., antimony, zinc, copper, and lead) were calculated based on stormwater samples collected in the cities of Milwaukie and Portland. Note that half-lives (i.e., the time required for the pollutant concentration to decline to half of the initial concentration because of degradation) were not assigned to metals because they do not degrade in the subsurface, and organic partitioning coefficients were not assigned to metals because they do not sorb to organic carbon. Technical documentation for the pollutant properties is presented in Attachment B.

5.2 Model Results

This section presents the results of the unsaturated zone GWPD model, including the protectiveness demonstration and Alternate Action Levels. Results of the unsaturated zone GWPD model apply to stormwater with pollutant concentrations typical of stormwater runoff from urban ROWs, and do not apply to releases of pollutants to the environment (i.e., spills). The model results should be considered along with the City's internal risk management goals to develop policy for stormwater management that is protective of the groundwater resource.

Protectiveness Demonstration

Table 5 presents the minimum protective vertical separation distances under the average and reasonable maximum scenarios of the unsaturated zone GWPD model. The model calculations for these scenarios are presented in Table 1 of Attachment C.

The average scenario represents most reasonably likely conditions, and is used for regulatory compliance. Under the average scenario, the minimum protective vertical separation distances are less than 1 foot. The largest minimum protective separation distance is for PCP (0.47 foot protective separation distance is significantly smaller than the protective separation distances calculated by other jurisdictions' unsaturated zone GWPDs, reflecting the fact that Milwaukie's UICs are sited in relatively fine-grained sediments. When demonstrating groundwater protectiveness, we recommend using a protective separation distance of 1.0 foot for the minimum separation distance instead of 0.47 foot. Using 1.0 foot conservatively accounts for uncertainties in the USGS (2008) depth to groundwater study (which is the basis for calculating separation distance).

The reasonable maximum scenario represents the worst-case conditions, and is characterized by compounding conservatism of input variables. The purpose of the reasonable maximum scenario is to evaluate model sensitivity, and it is not used for regulatory compliance.

All of the UICs within water well setbacks identified in Table 2 have significantly more than the minimum protective vertical separation distance of 1.0 foot. Specifically, separation distances for UICs in Table 2 range from 31 feet to 92 feet. Therefore, the minimum vertical separation distances in Table 5 demonstrate that City UICs within water well setbacks do not impair groundwater quality or supply based on an unsaturated zone GWPD, in accordance with Schedule A, Condition 6(b)(i) of the draft July 2012 UIC WPCF permit template.

Alternate Action Levels

Alternate Action Levels are shown in Table 6, and calculations for the Alternate Action Levels are provided in Table 2 of Attachment C. Under the average and reasonable maximum scenarios, zinc, copper, antimony, and DEHP attenuate to below the MRL before reaching the water table when initial concentrations in influent stormwater are equal to the Alternate Action Level. The Alternate Action Levels were developed using the following assumptions:

- Alternate Action Levels are limited to maximum concentrations of 10 times the existing Action Levels (antimony, zinc, and copper) or 5 times the existing Action Levels (i.e., DEHP, to keep the Action Level within the published range for DEHP solubility in water).
- The separation distance between the bottom of the UICs and the seasonal high groundwater is 1.0 foot so that the Alternate Action Levels apply to all but three City UICs (24027 and 44003 that discharge directly to groundwater, and 24008, which has 0.16 foot of vertical separation distance). The remaining UICs with known depths have vertical separation distances of more than 5 feet.
- Pollutant concentrations at or below the Alternate Action Level measured at the end of the inlet pipe to the UIC are attenuated to the MRL at or above the water table.

6. Conclusions and Recommendations

We make the following conclusions based on the unsaturated zone GWPD model:

- The 33 UICs within permit-specified setbacks to water wells are protective of the groundwater resource, and, therefore, have been addressed in accordance with Schedule A, Condition 6(b)(i) of the draft July 2012 UIC WPCF permit template. <u>These 33 UICs do not need to be retrofitted or decommissioned as a part of future CIP projects, based on the conditions of the draft July 2012 UIC WPCF permit template.</u>
- Three City UICs (44003, 24008, and 24027) have less than the minimum protective separation distance. <u>These UICs are outside of currently identified water well setbacks and require no action. However, if these UICs become included within a water well setback because of identification of new water wells in the future, action will be required.</u> Actions potentially include a saturated zone GWPD, demonstration that the newly identified water well is not at risk from the UIC using hydrogeologic methods, structural retrofit (e.g., backfilling), passive control, or decommissioning.
- Action Levels for zinc, antimony, copper, and DEHP can be adjusted to the levels in Table 6 and still be protective of groundwater for UICs with at least 1.0 foot of vertical separation distance.

The conclusions of this unsaturated zone GWPD regarding UICs within water well setbacks are based on a preliminary inventory of water wells, and do not consider UICs with unknown depths. We make the following recommendations so that the results of the unsaturated GWPD can be applied to all City UICs as additional water wells are identified and/or all UIC depths are measured. The following additional activities are required prior to completion of the system wide assessment and to comply with conditions outlined in the draft July 2012 UIC WPCF permit template.

- The City will need to continue to identify water wells as a part of its system-wide assessment. As UICs are identified within setbacks to newly identified water wells, the vertical separation distance at each UIC (Attachment A) must be compared to the minimum protective separation distance of 1.0 foot (as calculated as part of this GWPD). UICs are protective of groundwater when the separation distance is more than 1.0 foot.
- The City operates 32 UICs where the depth is unknown because the UIC is buried (Attachment A). These UICs will have to be uncovered and depth measured as a part of the system-wide assessment, and the vertical separation distance to seasonal high groundwater should be calculated.
    - If any of the 32 UICs are identified as being within newly identified water well setbacks (1 of the 32 UICs with unknown depth [UIC No. 34142] currently is identified as within a water well setback), compare the vertical separation distance at each UIC to the minimum protective separation distance of 1.0 foot. UICs are protective of groundwater when the vertical separation distance is more than 1.0 foot.
    - Determine if the Alternate Action Levels can be applied to the UICs by comparing the vertical separation distance at each UIC to the minimum protective separation distance of 1.0 foot. Alternate Action Levels can be applied to the UICs when the vertical separation distance is more than 1.0 foot.

References

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FIGURES

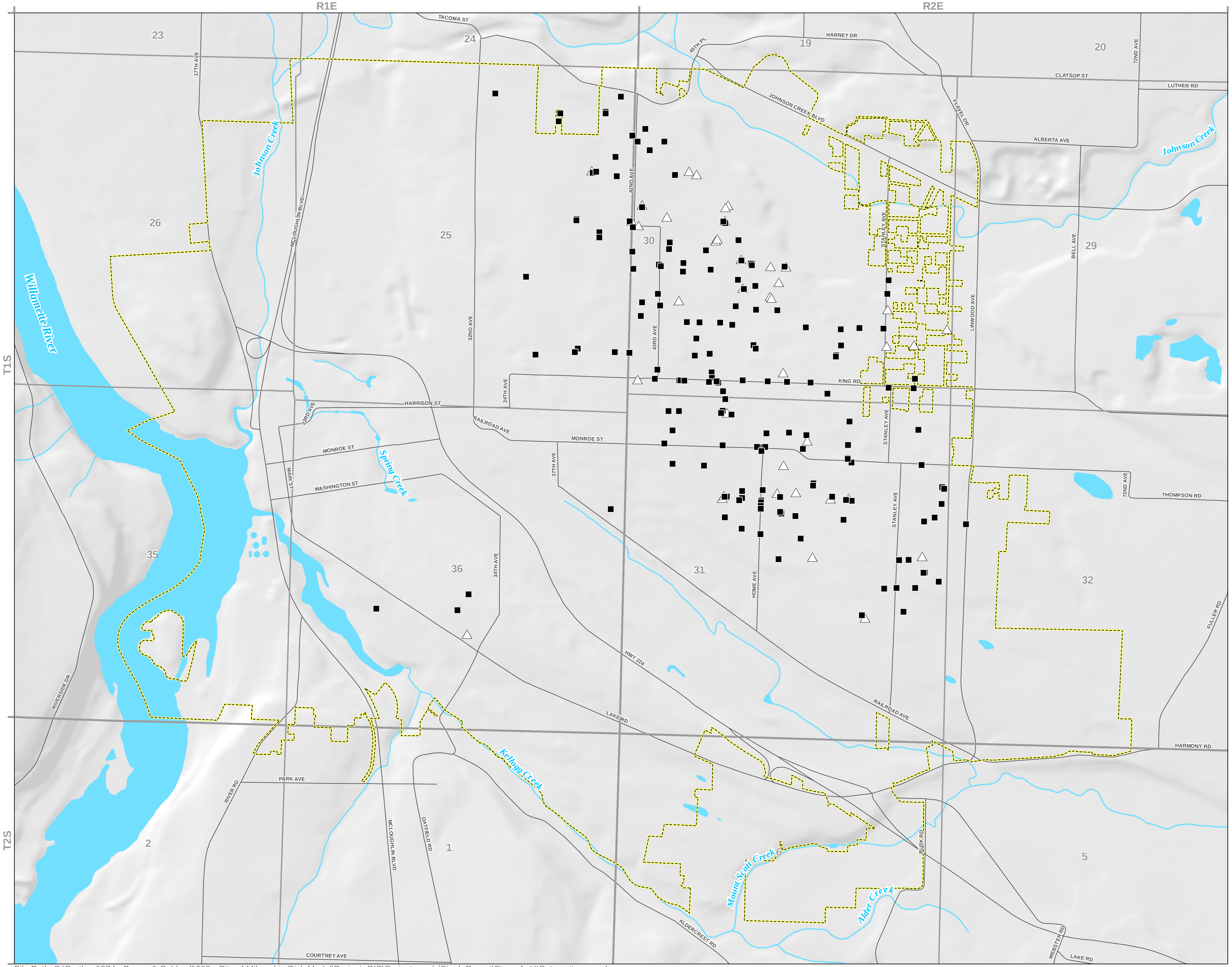


FIGURE 1

UIC Locations

City of Milwaukie

LEGEND

- UICs with Known Depth
- UICs with Unknown Depth

All Other Features

- Milwaukie City Limits
- Major Roads
- Watercourses
- Waterbodies

N

0 750 1,500 2,250

Feet

MAP NOTES:
Date: November 6, 2012
Data Sources: City of Milwaukie, DOGAMI, USGS, METRO RLIS

GSI Water Solutions, Inc.

File Path: P:\Portland\374 - Brown & Caldwell\003 - City of Milwaukie Risk Model\Project_GIS\Project_mxds\Final_Report\Figure1_UIC_Locations.mxd

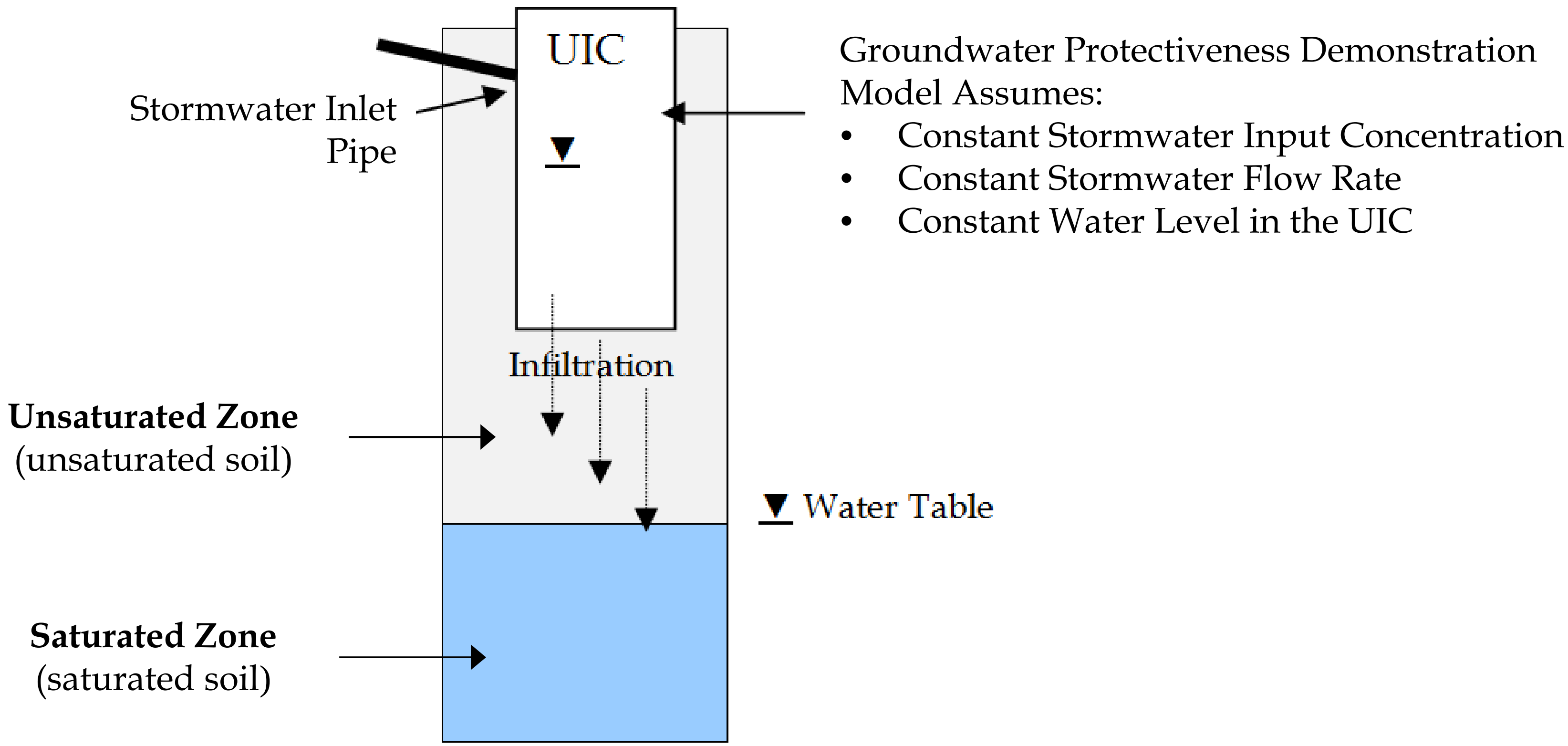
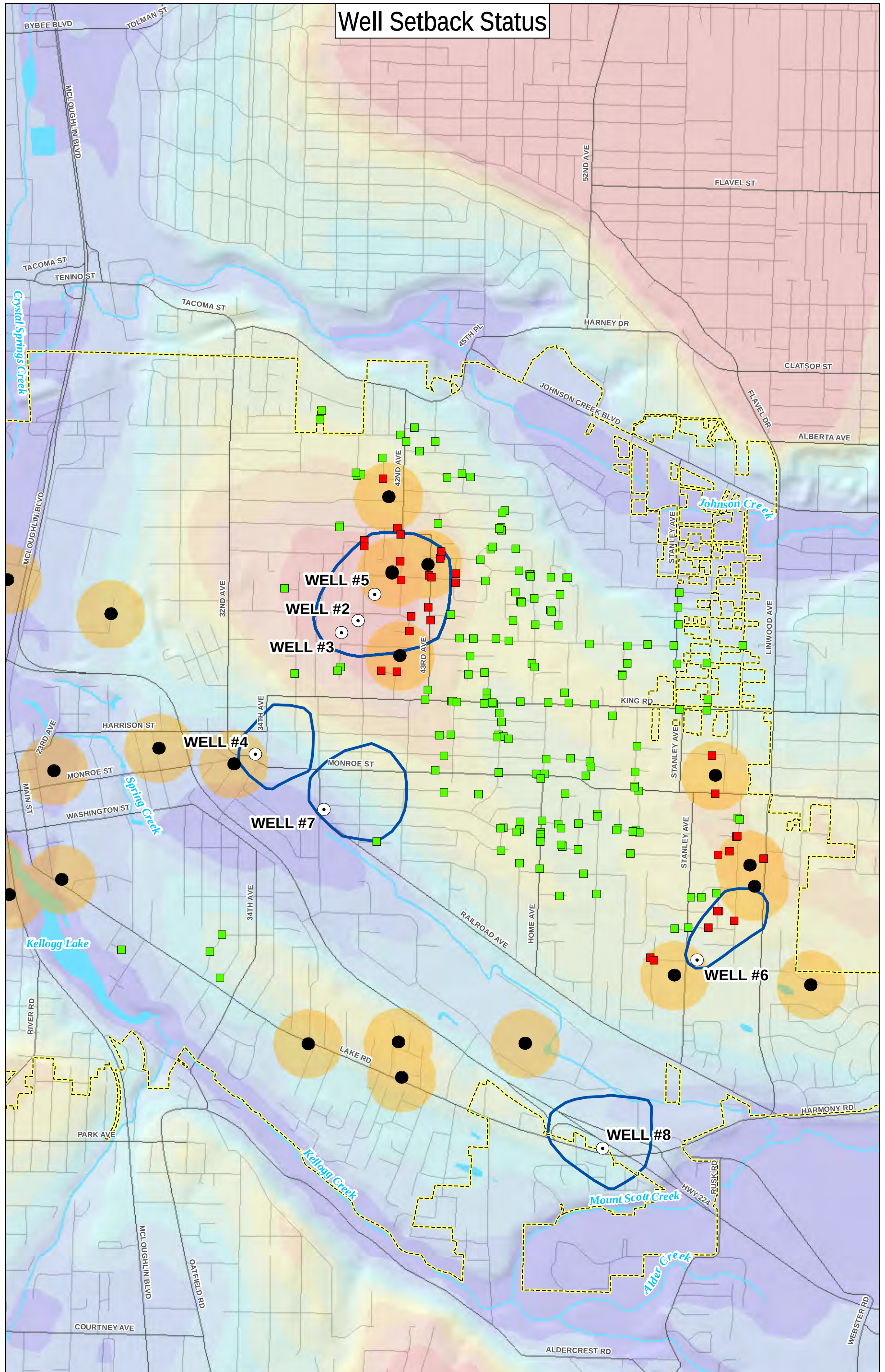


FIGURE 2
UIC Conceptual Model
City of Milwaukie



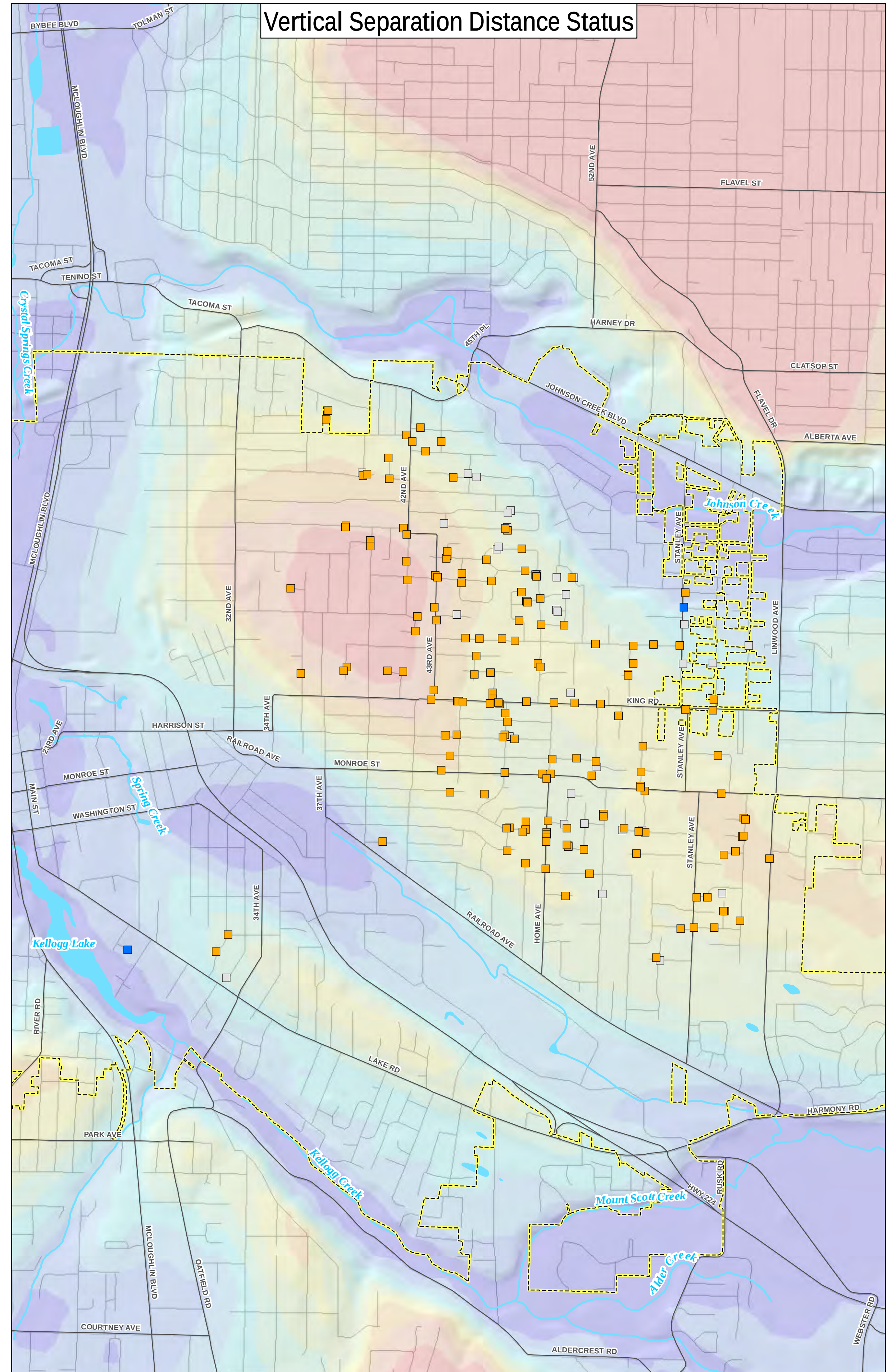


FIGURE 3

UIC Compliance Under July 2012 Permit Template

City of Milwaukie

LEGEND

UIC Locations

Well Setback Status

- Inside Well Setback - 33 Total
- Outside Well Setack - 163 Total

Vertical Separation Distance Status

- Wet Feet - 2 Total
- Dry Feet - 162 Total
- Dry/Wet Feet Unknown - 32 Total (Buried UIC)

Water Wells

- City of Milwaukie Water Supply Wells
- Private Wells

USGS (2008) Groundwater Depth

- 0 - 10 feet
- >10 - 20 feet
- >20 - 30 feet
- >30 - 40 feet
- >40 - 50 feet
- >50 - 60 feet
- >60 - 70 feet
- >70 - 80 feet
- >80 - 90 feet
- >90 - 100 feet

All Other Features

- 2 Year Time of Travel Zones
- 500 foot Setback from Private Wells
- Milwaukie City Limits
- Major Roads
- Minor Roads
- Watercourses
- Waterbodies

NOTE:
UICs inside well setbacks are within the 2 year time of travel zone of City of Milwaukie municipal wells or within 500 feet of private wells.

N

0 1,000 2,000 3,000
Feet

MAP NOTES:
Date: November 6, 2012
Data Sources: City of Milwaukie, OR DEQ, USGS, METRO RLIS

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File Path: P:\Portland\374 - Brown & Caldwell\003 - City of Milwaukie Risk Model\Project_GIS\Project_mxds\Final_Report\Figure3_July_2012_Permit_Template.mxd

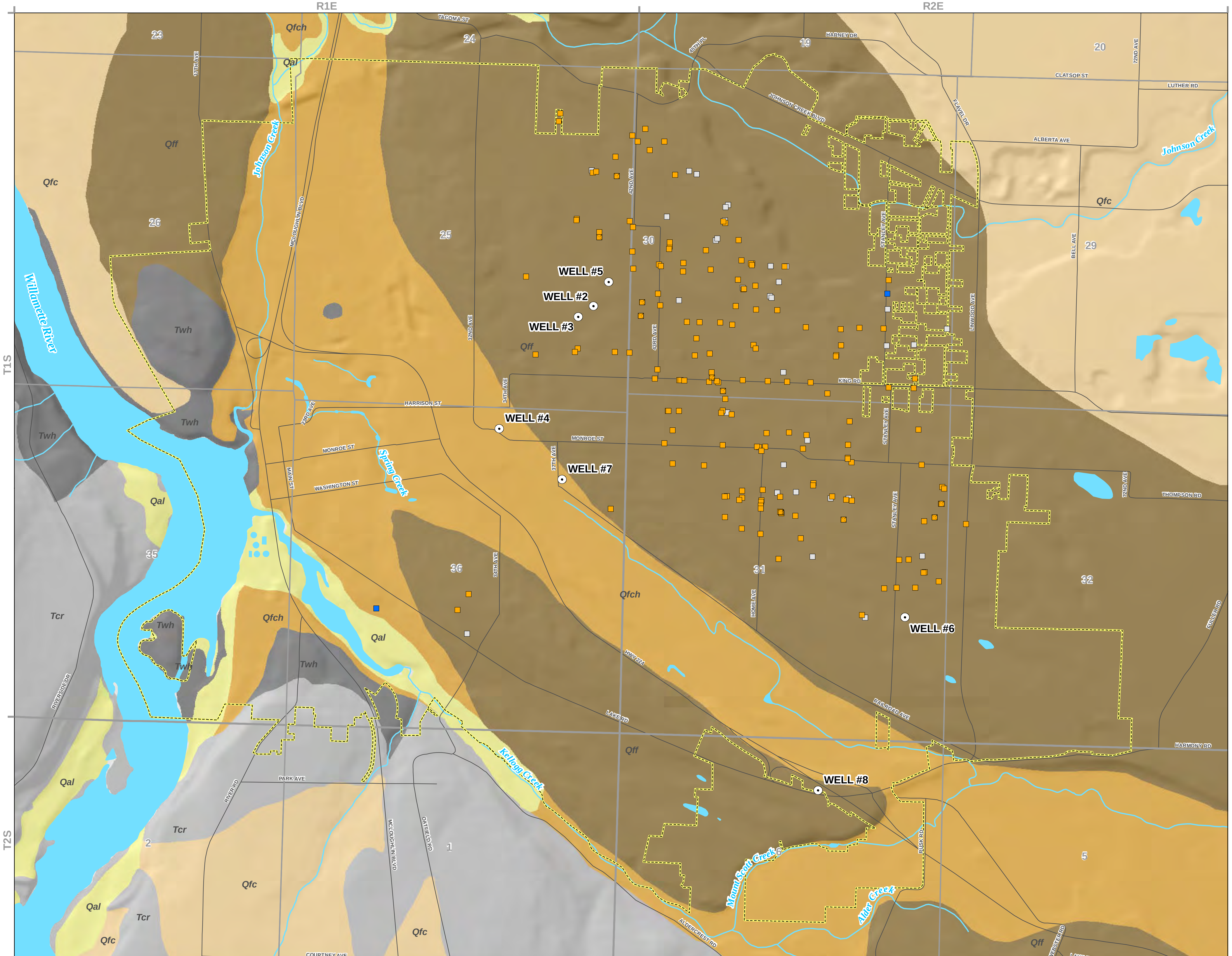

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FIGURE 4
Surficial Geology Map
City of Milwaukie

LEGEND

- City of Milwaukie Water Supply Wells

UIC Locations

- UIC Where Infiltration Test Was Conducted

Vertical Separation Status

- Wet Feet - 2 Total
- Dry Feet - 162 Total
- Dry/Wet Feet Unknown - 32 Total (Buried UIC)

Surficial Geology from DOGAMI

Quaternary Sedimentary Units

- Qal - Alluvium
- Qfc - Catastrophic flood deposits, coarse grained facies
- Qfch - Catastrophic flood deposits, channel facies
- Qff - Catastrophic flood deposits, fine grained facies

Miocene Basalt

- Tcr - Columbia River Basalt Group

Eocene Units

- Twh - Basalt of Waverly Heights and associated undifferentiated sedimentary rocks

All Other Features

- Milwaukie City Limits
- Major Roads
- Watercourses
- Waterbodies

N

0 750 1,500 2,250
Feet

MAP NOTES:
Date: November 6, 2012
Data Sources: City of Milwaukie, DOGAMI, USGS, METRO RLIS

GSI Water Solutions, Inc.

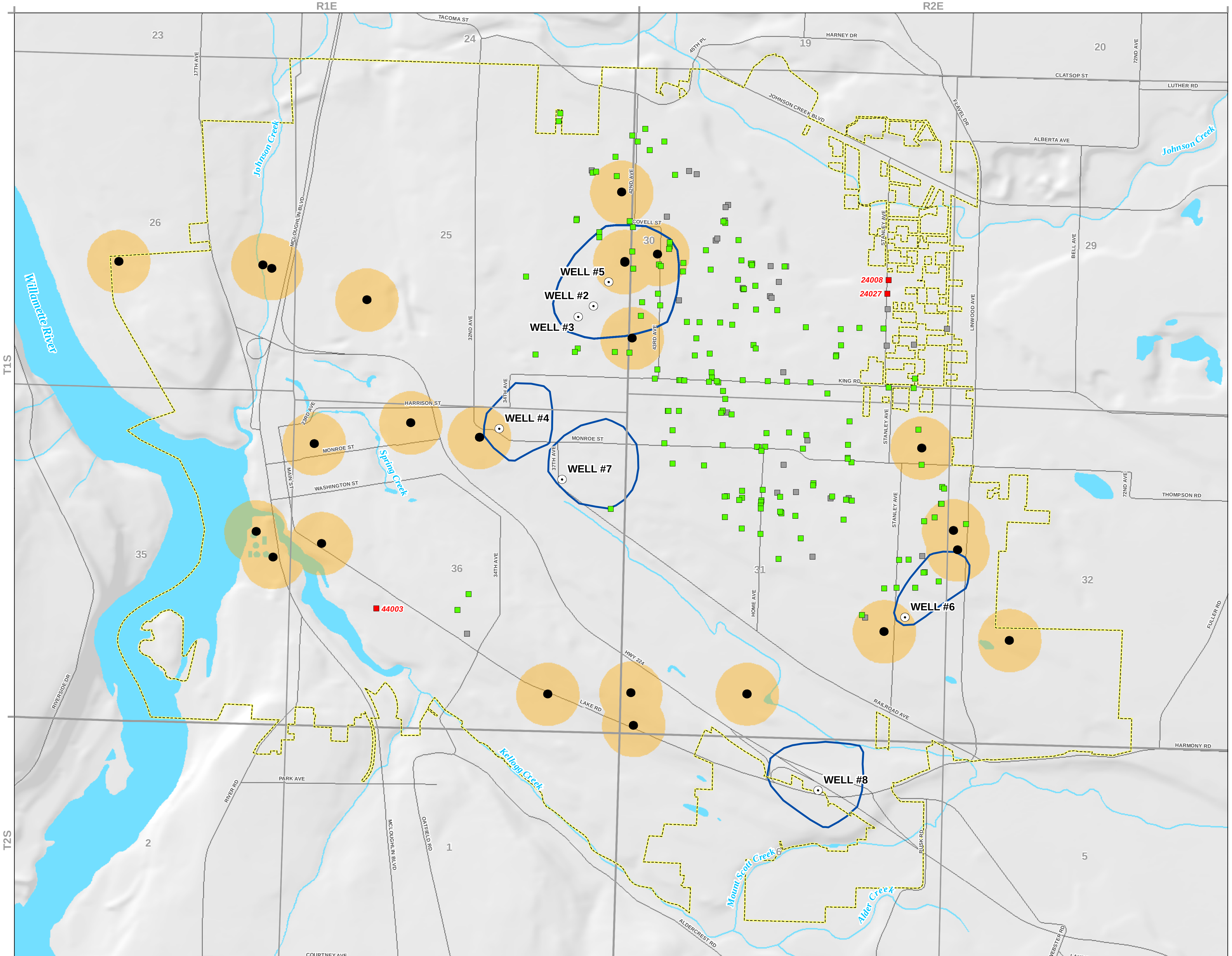

FIGURE 5

UIC Compliance Under
July 2012 Permit Template
City of Milwaukie

LEGEND

UIC Locations
- Compliant with Permit Conditions
- Separation Distance < 1.0 feet
- Depth Unknown

Water Wells
- City of Milwaukie Water Supply Wells
- Private Wells

All Other Features
- 2 Year Time of Travel Zones
- 500 foot Setback from Private Wells
- Milwaukie City Limits
- Major Roads
- Watercourses
- Waterbodies

N

0 750 1,500 2,250
Feet

MAP NOTES:
Date: November 6, 2012
Data Sources: City of Milwaukie, METRO RLIS, USGS

GSI Water Solutions, Inc.

File Path: P:\Portland\374 - Brown & Caldwell\003 - City of Milwaukie Risk Model\Project_GIS\Project_mxds\Final_Report\Figure5_July_2012_Permit_Template.mxd

TABLES

Table 1

Water Well Locations Within City of Milwaukie City Limits

City of Milwaukie, Oregon

OWRD Well ID	Water Right ID			Well Owner	Well Type	Data Source	Location Accuracy [4]
	Permit No.	Certificate No.	Claim No.				
CLAC 312				Robert Dwyer	Irrigation	City Private Well Database [1]	Property
CLAC 316				Dr. George Corti	Domestic	City Private Well Database [1]	Property
CLAC 317				Raymond Gitch	Domestic	City Private Well Database [1]	Property
CLAC 318				O. L. Wilson	Domestic	City Private Well Database [1]	Property
CLAC 354				Zon Wells	Domestic	City Private Well Database [1]	Property
CLAC 355				Ralph Elser	Domestic	City Private Well Database [1]	Property
CLAC 358				OMARK Properties	Domestic	City Private Well Database [1]	Property
CLAC 362				Donald Calderwood	Domestic	City Private Well Database [1]	Property
CLAC 364				Walter Freeman	Domestic	City Private Well Database [1]	Property
CLAC 366				J. E. Powers	Domestic	City Private Well Database [1]	Property
CLAC 367				Ambrose Calcagno	Domestic	City Private Well Database [1]	Property
CLAC 376						City Private Well Database [1]	Property
CLAC 378				Archie Timmons	Domestic	City Private Well Database [1]	Property
CLAC 3979				Union High School District	Irrigation	City Private Well Database [1]	Property
CLAC 3986				M. A. Warner	Domestic	City Private Well Database [1]	Property
CLAC 56001				Water Environmental Services	Irrigation	City Private Well Database [1]	Property
	G-13719			Clackamas County Service District 1		OWRD Water Rights Database [2]	Water Right
			GR-2877	OMARK Industries		OWRD Water Rights Database [2]	QQ Section
	G-776	24592		Ralph Elser		OWRD Water Rights Database [2]	QQ Section
	G-251	29069		Ambrose Calcagno		OWRD Water Rights Database [2]	Water Right
	G-3041	37507		OMARK Properties		OWRD Water Rights Database [2]	Water Right
	G-4276	37508		OMARK Properties		OWRD Water Rights Database [2]	Water Right
	G-2619	38040		Wilfred C. Wilhelm		OWRD Water Rights Database [2]	Water Right
	G-4855	38217		Clinton C. Warren		OWRD Water Rights Database [2]	Water Right
			GR-1478	City of Milwaukie Well No. 2 [5]	Municipal	City Municipal Well Database [3]	Lat/Long
			GR-1480	City of Milwaukie Well No. 3 [5]	Municipal	City Municipal Well Database [3]	Lat/Long
	G-1609	32158		City of Milwaukie Well No. 4 [5]	Municipal	City Municipal Well Database [3]	Lat/Long
	G-2542	34010		City of Milwaukie Well No. 5 [5]	Municipal	City Municipal Well Database [3]	Lat/Long
	G-9953	56403		City of Milwaukie Well No. 6 [5]	Municipal	City Municipal Well Database [3]	Lat/Long
	G-9954	56404		City of Milwaukie Well No. 7 [5]	Municipal	City Municipal Well Database [3]	Lat/Long
	G-10582	82571		City of Milwaukie Well No. 8 [5]	Municipal	City Municipal Well Database [3]	Lat/Long

Notes:

[1] Data provided by City in the "privatewell_pts" shapefile. CL19965 was excluded because the on-line OWRD well log search indicates that it is a monitoring well.

[2] Data provided by City in the "water_rights_within_Milwaukie" shapefile. Only groundwater rights were included.

[3] Data provided by the City in the "wells" shapefile.

[4] Location accuracy:

Property: wells located by address, and therefore are accurate to the property on which the well is located

QQ Section: wells located to the nearest quarter quarter section based on information from OWRD are accurate to +/- 1,320 feet

Water Right: wells located using legal description in the water right, location is considered to be highly accurate

Lat/Long: wells located by latitude and longitude coordinates

[5] Water Right ID from West Yost Associates (2011)

Table 2

Active UICs Within Water Well Setbacks

City of Milwaukie, Oregon

UIC ID	Address	Longitude	Latitude	ADT	UIC Depth (feet)	Average DTW (feet)	Seasonal High DTW (feet)	Vertical Separation Distance (feet)	Within 2 Year Time of Travel	Within 500 feet of Private Well
24018	5844 SE HARRISON ST	-122.602345	45.446119	<1000 ADT	23.30	57.32	54.32	31.02		X
34138	5866 SE LLOYD ST	-122.602303	45.439283	<1000 ADT	25.00	61.25	58.25	33.25	X	
34136	11576 SE 59TH AV	-122.601816	45.439943	<1000 ADT	21.00	65.02	62.02	34.02	X	
34141	5565 SE HARLOW ST	-122.605514	45.438041	<1000 ADT	18.00	58.26	55.26	37.26		X
24021	5838 SE MONROE ST	-122.602094	45.444602	>1000 ADT	29.50	69.81	66.81	37.31		X
34034	4341 SE ROCKWOOD ST	-122.617913	45.453768	<1000 ADT	35.50	77.52	74.52	39.02	X	X
34140	4341 SE ROCKWOOD ST	-122.617924	45.453945	<1000 ADT	32.60	74.81	71.81	39.21	X	X
34135	11496 SE 59TH AV	-122.601738	45.439957	<1000 ADT	22.00	64.77	61.77	39.77	X	
34013	4102 SE WAKE CT	-122.621291	45.456756	<1000 ADT	25.00	69.30	66.30	41.30		X
34137	11557 SE 60TH AV	-122.600868	45.439578	<1000 ADT	19.50	64.77	61.77	42.27	X	
34139	11221 SE LINWOOD AV	-122.599279	45.442087	<1000 ADT	25.92	71.60	68.60	42.68		X
34128	11114 SE 60TH AV	-122.600851	45.442936	<1000 ADT	24.00	70.90	67.90	43.90		X
34036	9656 SE 44TH AV	-122.617054	45.453077	<1000 ADT	26.08	73.99	70.99	44.91		X
34130	5965 SE DERDAN CT	-122.601224	45.442342	<1000 ADT	19.00	72.64	69.64	50.64		X
34037	4402 SE HOWE ST	-122.617067	45.452702	>1000 ADT	19.58	73.99	70.99	51.41		X
34027	9405 SE 42ND AV	-122.620217	45.454567	>1000 ADT	27.20	81.94	78.94	51.74	X	
34045	9665 SE 43RD AV	-122.618559	45.452972	>1000 ADT	33.50	88.64	85.64	52.14	X	X
34035	9616 SE 43RD AV	-122.617949	45.453664	>1000 ADT	21.80	77.52	74.52	52.72	X	X
34131	5922 SE DERDAN CT	-122.601853	45.442174	<1000 ADT	14.75	70.80	67.80	53.05		X
34129	11114 SE 60TH AV	-122.600810	45.442947	<1000 ADT	14.60	70.90	67.90	53.30		X
34142	5620 SE HARLOW ST	-122.605325	45.437930	<1000 ADT	0.00	57.88	54.88	54.88		X
34087	10205 SE 41ST CT	-122.621115	45.449139	<1000 ADT	34.00	94.83	91.83	57.83		X
34025	4145 SE OLSEN ST	-122.620413	45.454822	>1000 ADT	17.93	81.94	78.94	61.01		X
34088	10236 SE 41ST CT	-122.620227	45.449127	<1000 ADT	27.42	91.44	88.44	61.02		X
34029	9475 SE 40TH AV	-122.622262	45.454301	>1000 ADT	28.11	92.29	89.29	61.18	X	
34176	9918 SE 43RD AV	-122.618401	45.451205	>1000 ADT	22.00	86.44	83.44	61.44	X	
34030	9631 SE 42ND AV	-122.620212	45.453502	>1000 ADT	29.50	95.29	92.29	62.79	X	X
34147	9523 SE 40TH AV	-122.622262	45.454084	<1000 ADT	26.20	92.29	89.29	63.09	X	
34047	9839 SE 43RD AV	-122.618569	45.451708	>1000 ADT	20.00	86.44	83.44	63.44	X	
34033	4243 SE HARVEY ST	-122.619583	45.450734	<1000 ADT	24.00	91.88	88.88	64.88	X	X
34046	9660 SE 43RD AV	-122.618429	45.452911	>1000 ADT	22.00	88.64	85.64	65.84	X	X
34031	9738 SE 42ND AV	-122.620121	45.452766	>1000 ADT	23.30	94.32	91.32	68.02	X	X
34032	4207 SE HARVEY ST	-122.619517	45.451329	<1000 ADT	23.00	94.96	91.96	69.96	X	

Notes

UIC ID = Underground Injection Control Device Identification Number

ADT = Average Daily Traffic Volume in Trips per Day

W = Depth to Groundwater

Table 3

Model Input Parameters – Soil Properties

City of Milwaukie, Oregon

Input Parameter	Units	Average Scenario	Reasonable Maximum Scenario	Data Source and Location of Technical Documentation
Total Porosity (η)	-	0.375	0.375	Midrange porosity for a sand, Freeze and Cherry (1979) Table 2.4. Appendix B, Section 2.1.1.
Effective Porosity (η_e)	-	0.31	0.31	Effective porosity of the USA hydrogeologic unit (USGS, 2008). Appendix B, Sections 2.1.1 and 2.1.4.
Bulk Density (ρ_b)	g/cm^3	1.66	1.66	Calculated by equation 8.26 in Freeze and Cherry (1979). Appendix B, Section 2.1.2.
Dispersivity (α)	m/d	5% of transport distance	5% of transport distance	Calculated based on Gelhar (1985). Appendix B, Section 2.1.3.
Pore Water Velocity (v)	m/d	0.365	0.746	Based on 11 infiltration tests conducted by City staff. Average scenario uses the median velocity, reasonable maximum scenario uses the 95% UCL velocity. Appendix B, Section 2.1.4 and Section 4.0.

Notes

g/cm^3 = grams per cubic centimeter

m/d = meters per day

95% UCL = 95% Upper Confidence Limit on the mean

(-) = input parameter units are dimensionless

Table 4

Model Input Parameters – Pollutant Properties

City of Milwaukie, Oregon

Input Parameter	Units	Pollutant	Average Scenario	Reasonable Maximum Scenario	Data Source and Location of Technical Documentation
Initial Concentration	µg/L	PCP	10	10	Action Level in July 2012 permit template
		DEHP	60	60	Action Level in July 2012 permit template
		B(a)P	2	2	Action Level in July 2012 permit template
		Lead	500	500	Action Level in July 2012 permit template
Organic Carbon Partitioning Coefficient (K_{oc})	L/Kg	PCP	877	703	EPA (1996), assuming a pH of 6.4. Appendix B, Section 2.3.1.
		DEHP	12,200	12,200	Calculated based on equations in Roy and Griffin (1985). Appendix B, Section 2.3.1.
		B(a)P	282,185	282,185	
Distribution Coefficient (K_d)	L/Kg	PCP	18.3	1.7	Calculated based on Equation 5.12 in Watts (1998). Appendix B, Section 2.3.2.
		DEHP	254	29	Calculated based on Equation 5.12 in Watts (1998). Appendix B, Section 2.3.2.
		B(a)P	5,870	670	Calculated based on Equation 5.12 in Watts (1998). Appendix B, Section 2.3.2.
		Antimony	25,000	9,700	Calculated from City of Portland stormwater discharge monitoring data. Appendix B, Section 2.3.2.
		Zinc	53,000	22,500	
		Copper	159,000	25,000	Calculated from City of Milwaukie stormwater discharge monitoring data. Appendix B, Section 2.3.2.
		Lead	1,200,000	535,000	
Half Life (h)	d	PCP	31.4	49.9	Literature values. Appendix B, Section 2.3.3.
		DEHP	46.2	69.3	Literature values. Appendix B, Section 2.3.3.
		B(a)P	533	2,666	Literature values. Appendix B, Section 2.3.3.
Retardation Factor (R)	-	PCP	82	8.4	Calculated based on Equation (9.14) in Freeze and Cherry (1979). Appendix B, Section 2.3.4.
		DEHP	1,100	130	
		B(a)P	26,000	3,000	
		Antimony	25,000	9,700	
		Zinc	53,000	22,500	
		Copper	160,000	25,000	
		Lead	1,200,000	550,000	

Notes

d = days

L/Kg = Liters per Kilogram

µg/L = micrograms per liter

DEHP = di(2-ethylhexyl) phthalate

(-) = input parameter units are dimensionless

PCP = pentachlorophenol

B(a)P = benzo(a)pyrene

GSI Water Solutions, Inc.

Table 5

Protective Vertical Separation Distances

City of Milwaukie, Oregon

Pollutant	**MRL** (µg/L)	**Minimum Protective Vertical Separation Distance** (feet)	
		Average Scenario	Reasonable Maximum Scenario
Lead [1]	0.1	0.00929	0.043
Benzo(a)pyrene	0.01	0.00145	0.02586
PCP	0.04	0.47	9.34
DEHP	1	0.029	0.52

Notes:

MRL = method reporting limit

µg/L = micrograms per liter

PCP = pentachlorophenol

DEHP = di(2-ethylhexyl)phthalate

[1] Metals transport simulations are longer than 13.75 days because metals do not biodegrade over time. Metals transport simulations assume 1000 years of transport at 13.75 days per year = 13,750 days of transport.

[2] The vertical separation distance in the unsaturated zone that is necessary for pollutant concentrations to attenuate to below the method reporting limit.

Table 6

Proposed Alternate Action Levels (UICs $\geq$ 1 Feet Vertical Separation Distance)

City of Milwaukie, Oregon

Pollutant	MRL (µg/L) [1]	Existing Action Level (µg/L) [2]	Alternate Action Level (µg/L) [3]	Output Concentration (µg/L) [4]	
				Average Scenario	Reasonable Maximum Scenario
Antimony	0.1	6	60	0	0
Copper	0.1	1,000	10,000	0	0
Zinc	0.5	5,000	50,000	0	0
DEHP	1	60	300	0	0

Notes:

µg/L = micrograms per liter

UCL = upper confidence limit

MRL = method reporting limit

DEHP = di(2-ethylhexyl)phthalate

[1] Method Reporting Limit (MRL) based on typically achievable MRLs during the Gresham winter 2009 - 2010 stormwater monitoring event.

[2] Existing Action Levels from the draft July 2012 UIC WPCF permit template

[3] Alternate Action Levels are based on the "average transport scenario" of the GWPD model and the assumption that groundwater is protected when pollutant concentrations just above the water table are below the MRL. The Alternate Action Level is the input concentration of the pollutant entering the UIC in the unsaturated zone GWPD model.

[4] Output concentration is the concentration below the UIC after 1 foot of transport.

ATTACHMENTS

Attachment A

UIC Preliminary System-Wide Assessment

City of Milwaukie, Oregon

UIC ID	Address	Owner	Type	Qualifier	Raised	Longitude	Latitude	ADT	Impervious Area (square feet)	UIC Depth	Average Depth to Water (feet)	Seasonal High DTW (feet)	Surface Elevation	Vertical Separation Distance	Within 2 Year Time of Travel	Within 500ft of Private Well
Active UICs																
24006	4725 SE FIELDCREST AV	MILW	TYP1	NOT RAISED LOCATED UNDER BROKEN DRIVEWAY APPROACH.	Not Rasied	-122.614392	45.455626	<1000 ADT	55370	UNKNOWN	51.15	48.15	157.36	48.15		
24007	4718 SE FIELDCREST AV	MILW	TYP1	NOT RAISED BEHIND CURB, NEAR JAPANESE MAPLE.	Not Rasied	-122.614553	45.455533	<1000 ADT	53370	UNKNOWN	51.15	48.15	158.80	48.15		
24009	3898 SE WAKE ST	MILW	TYP1	NOT RAISED IN STREET.	Not Rasied	-122.622829	45.456972	<1000 ADT	46214	UNKNOWN	70.19	67.19	158.55	67.19		
24031	9920 SE STANLEY AV	MILW	TYP2	WEEK 2 MORE ON MAPLE, SOUTH OF ADDRESS**READ COMMENTS**		-122.604428	45.451298	>1000 ADT	8129	UNKNOWN	30.74	27.74	0.00	27.74		
24032	10114 SE STANLEY AV	MILW	TYP2	WEEK 2		-122.604442	45.449723	>1000 ADT	7248	UNKNOWN	43.66	40.66	0.00	40.66		
24033	5907 SE HECTOR ST	MILW				-122.602761	45.449794	<1000 ADT	12351	UNKNOWN	38.91	35.91	0.00	35.91		
34015	4489 SE MASON HILL DR	MILW	TYP1	NOT RAISED	Not Rasied	-122.616848	45.457049	<1000 ADT	37483	UNKNOWN	50.94	47.94	155.52	47.94		
34016	4508 SE MASON HILL DR	MILW	TYP1	NOT RAISED UNDER SMALL RETAINING WALL(BLOCKS) BEHIND SIDEWALK.	Not Rasied	-122.616371	45.456929	<1000 ADT	37483	UNKNOWN	50.94	47.94	155.46	47.94		
34019	4302 SE FIELDCREST DR	MILW	TYP1	NOT RAISED 5' BEHIND WATER METER BOX IN YARD.	Not Rasied	-122.618132	45.455054	<1000 ADT	34400	UNKNOWN	72.88	69.88	161.85	69.88		
34020	4705 SE FIELDCREST DR	MILW	TYP1	NOT RAISED IN GRASS.	Not Rasied	-122.614566	45.454959	<1000 ADT	40200	UNKNOWN	55.17	52.17	158.01	52.17		
34043	4674 SE ARDEN ST	MILW	TYP1	NOT RAISED IN GRASS YARD BEHIND CATCH BASIN.	Not Rasied	-122.615106	45.454084	<1000 ADT	37010	UNKNOWN	58.50	55.50	159.40	55.50		
34053	4906 SE WINWORTH CT	MILW	TYP1	NOT RAISED	Not Rasied	-122.611684	45.453031	<1000 ADT	63057	UNKNOWN	51.86	48.86	167.75	48.86		
34055	5082 SE WINWORTH CT	MILW	TYP1	NOT RAISED	Not Rasied	-122.610735	45.453034	<1000 ADT	32385	UNKNOWN	49.57	46.57	171.04	46.57		
34057	4823 SE WILLOW ST	MILW	TYP1	NOT RAISED	Not Rasied	-122.613368	45.452050	<1000 ADT	9452	UNKNOWN	57.78	54.78	163.03	54.78		
34062	9802 SE 50TH AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.611162	45.452356	<1000 ADT	26782	UNKNOWN	54.34	51.34	174.58	51.34		
34063	4906 SE LEONE LN	MILW	TYP1	NOT RAISED	Not Rasied	-122.611673	45.451733	<1000 ADT	12776	UNKNOWN	56.25	53.25	173.52	53.25		
34064	4928 SE LEONE LN	MILW	TYP1	NOT RAISED	Not Rasied	-122.611590	45.451662	<1000 ADT	13776	UNKNOWN	58.49	55.49	173.82	55.49		
34072	10276 SE 56TH AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.610743	45.448454	<1000 ADT	28855	UNKNOWN	63.75	60.75	184.70	60.75		
34078	10594 SE 47TH AV	MILW	TYP1	NOT RAISED UNDER SIDEWALK	Not Rasied	-122.614132	45.446645	<1000 ADT	65818	UNKNOWN	53.37	50.37	153.61	50.37		
34096	5445 SE WOODHAVEN ST	MILW	TYP1	NOT RAISED	Not Rasied	-122.606523	45.443084	<1000 ADT	36475	UNKNOWN	64.52	61.52	172.94	61.52		
34100	11015 SE 54TH AV	MILW	TYP1	NOT RAISED UNDER DRIVEWAY.	Not Rasied	-122.607646	45.443058	<1000 ADT	32357	UNKNOWN	56.42	53.42	165.60	53.42		
34104	11400 SE WOOD AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.608657	45.440504	<1000 ADT	133879	UNKNOWN	54.15	51.15	153.92	51.15		
34117	5151 SE ELK ST	MILW	TYP1	NOT RAISED.	Not Rasied	-122.610570	45.444452	<1000 ADT	23304	UNKNOWN	52.92	49.92	156.62	49.92		
34118	11107 SE 51ST AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.610909	45.443233	<1000 ADT	27969	UNKNOWN	53.14	50.14	155.79	50.14		
34120	11021 SE 52ND AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.609779	45.443284	<1000 ADT	67385	UNKNOWN	53.51	50.51	157.74	50.51		
34132	5918 SE SUNDIAL CT	MILW	TYP1			-122.601920	45.440655	<1000 ADT	41260	UNKNOWN	67.53	64.53	185.01	64.53		
34142	5620 SE HARLOW ST	MILW	TYP1	NOT RAISED	Not Rasied	-122.605325	45.437930	<1000 ADT	35647	UNKNOWN	57.88	54.88	158.57	54.88		Yes
34149	10706 SE 52ND AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.609144	45.445537	<1000 ADT	9060	UNKNOWN	57.98	54.98	169.37	54.98		
34160	4409 SE MELODY LN	MILW	TYP1	NOT RAISED	Not Rasied	-122.617274	45.451452	<1000 ADT	11927	UNKNOWN	74.29	71.29	151.63	71.29		
34189	4661 SE ARDEN ST	MILW	TYP1	NOT RAISED	Not Rasied	-122.615012	45.454168	<1000 ADT	7269	UNKNOWN	58.50	55.50	0.00	55.50		
34190	10000 SE WICHITA AV	MILW				-122.600770	45.450520	<1000 ADT	30030	UNKNOWN	24.41	21.41	36.00	21.41		
44006	11973 SE 33RD AV	MILW	TYP1	NOT RAISED	Not Rasied	-122.629735	45.436785	<1000 ADT	8402	UNKNOWN	44.95	41.95	0.00	41.95		
34186	3667 SE ROSWELL ST	MILW	TYP1	ON SOUTH END OF FIELD- MIDDLE OF PARK CAN NOT ACCESS WITH VACTOR		-122.624930	45.459054	<1000 ADT	0	9.83	59.10	56.10	0.00	46.27		
24008	5662 SE WILLOW ST	MILW	TYP1			-122.604421	45.452565	<1000 ADT	18068	10.92	14.08	11.08	140.75	0.16		
34134	5804 SE SUNDIAL CT	MILW	TYP1			-122.603330	45.440474	<1000 ADT	34208	12.00	65.79	62.79	179.09	50.79		
34167	11630 SE STANLEY AV	MILW	TYP1			-122.603436	45.439258	<1000 ADT	18034	12.00	59.19	56.19	162.50	44.19		
34187	3667 SE ROSWELL ST	MILW	TYP1	NORTH EAST SIDE OF PARK CAN NOT ACCESS WITH VACTOR		-122.624861	45.459401	<1000 ADT	0	13.75	59.10	56.10	0.00	42.35		
24025	4351 SE JACKSON ST	MILW	TYP1	ACROSS FROM THIS ADDRESS, ACTUALLY ON THE CHURCH PROPERTY		-122.617450	45.445817	<1000 ADT	7099	14.00	73.86	70.86	186.75	56.86		
34129	11114 SE 60TH AV	MILW	TYP1			-122.600810	45.442947	<1000 ADT	27731	14.60	70.90	67.90	197.85	53.30		Yes
34131	5922 SE DERDAN CT	MILW	TYP1			-122.601853	45.442174	<1000 ADT	17368	14.75	70.80	67.80	195.36	53.05		Yes
34085	10317 SE 46TH AV	MILW	TYP1			-122.615124	45.448144	<1000 ADT	18090	15.60	56.41	53.41	150.71	37.81		
34021	4710 SE FIELDCREST DR	MILW	TYP1			-122.614542	45.454843	<1000 ADT	40200	16.08	55.17	52.17	158.94	36.09		
34175	5238 SE PARK ST	MILW	TYP1			-122.609403	45.441290	<1000 ADT	19138	16.08	54.72	51.72	155.18	35.64		
34154	4703 SE MONROE ST	MILW	TYP2	WEEK 3		-122.614349	45.445229	>1000 ADT	22823	16.18	56.20	53.20	164.86	37.02		
24027	9878 SE STANLEY AV	MILW	TYP1	USED TO BE CLACKAMAS COUNTY		-122.604486	45.451968	<1000 ADT	7037	16.80	19.74	16.74	154.71	-6.00		
24029	4335 SE MONROE ST	MILW	TYP2	WEEK 3 WEST CORNER OF THE PROPERTY, ACTUALLY CLOSER TO THE CHURCH		-122.617922	45.445251	>1000 ADT	2547	17.00	70.32	67.32	185.81	50.32		
34025	4145 SE OLSEN ST	MILW	TYP2			-122.620413	45.454822	>1000 ADT	48261	17.93	81.94	78.94	156.60	61.01		Yes
34141	5565 SE HARLOW ST	MILW	TYP1			-122.605514	45.438041	<1000 ADT	35647	18.00	58.26	55.26	158.78	37.26		Yes
34146	4318 SE JEFFERSON ST	MILW	TYP1	ON SHOULDER NEAR FENCE.		-122.617392	45.444387	<1000 ADT	52189	18.11	67.85	64.85	181.65	46.74		
64001	4097 SE RIO VISTA ST	MILW	TYP2	WEEK 4		-122.621124	45.442355	<1000 ADT	5047	18.17	26.97	23.97	114.05	5.80		
34010	4264 SE MEADOWCREST CT	MILW	TYP1			-122.619290	45.457908	<1000 ADT	45987	18.25	59.37	56.37	157.35	38.12		
34181	11192 SE 52ND CT	MILW	TYP1			-122.610719	45.442421	<1000 ADT	9590	18.50	54.53	51.53	153.47	33.03		
34133	5840 SE SUNDIAL CT	MILW	TYP1			-122.602745	45.440488	<1000 ADT	20705	18.83	67.53	64.53	181.29	45.70		
34056	4889 SE ROBERTA LN	MILW	TYP1			-122.613681	45.452406	<1000 ADT	40983	19.00	61.71	58.71	162.50	39.71		
34130	5965 SE DERDAN CT	MILW	TYP1			-122.601224	45.442342	<1000 ADT	17367	19.00	72.64	69.64	195.16	50.64		Yes
34158	4766 SE WASHINGTON PL	MILW	TYP1			-122.613078	45.442974	<1000 ADT	3175	19.00	58.77	55.77	169.67	36.77		
34161	5129 SE KING RD	MILW	TYP2	WEEK 3		-122.610491	45.448048	>1000 ADT	29000	19.00	63.56	60.56	182.45	41.56		
34162	5253 SE KING RD	MILW	TYP2	WEEK 3		-122.609041	45.448051	>1000 ADT	24970	19.00	64.97	61.97	192.13	42.97		
34157	11168 SE 52ND AV	MILW	TYP1			-122.609773	45.442253	<1000 ADT	19730	19.33	53.31	50.31	154.85	30.98		
34054	5082 SE WINWORTH CT	MILW	TYP1			-122.610838	45.453033	<1000 ADT	32357	19.50	49.57	46.57	171.23	27.07		
34073	5011 SE KING RD	MILW	TYP2	WEEK 3		-122.611677	45.448056	>1000 ADT	146899	19.50	61.50	58.50	175.95	39.00		

UIC ID	Address	Owner	Type	Qualifier	Raised	Longitude	Latitude	ADT	Impervious Area (square feet)	UIC Depth	Average Depth to Water (feet)	Seasonal High DTW (feet)	Surface Elevation	Vertical Separation Distance	Within 2 Year Time of Travel	Within 500ft of Private Well
34097	5502 SE WOODHAVEN ST	MILW	TYP1			-122.606329	45.442985	<1000 ADT	36475	19.50	64.52	61.52	174.59	42.02		
34137	11557 SE 60TH AV	MILW	TYP2	WEEK 4		-122.600868	45.439578	<1000 ADT	85446	19.50	64.77	61.77	174.07	42.27	Yes	
34037	4402 SE HOWE ST	MILW	TYP2	WEEK 1		-122.617067	45.452702	>1000 ADT	33457	19.58	73.99	70.99	155.90	51.41		Yes
34069	4543 SE LOGUS RD	MILW	TYP2	WEEK 2		-122.615970	45.450520	>1000 ADT	60284	19.60	67.93	64.93	152.59	45.33		
34152	9667 SE 49TH AV	MILW	TYP2	WEEK 1		-122.612841	45.453050	>1000 ADT	14151	19.60	55.53	52.53	164.35	32.93		
34066	9903 SE 49TH AV	MILW	TYP2	WEEK 1		-122.612521	45.451132	>1000 ADT	35520	19.67	59.59	56.59	168.49	36.92		
34081	4501 SE RHODESA ST	MILW	TYP1			-122.616130	45.449826	<1000 ADT	68068	19.83	65.81	62.81	151.88	42.98		
34093	5510 SE JACKSON ST	MILW	TYP1			-122.606652	45.445390	<1000 ADT	122825	19.92	61.64	58.64	182.99	38.72		
34014	4422 SE MASON HILL DR	MILW	TYP1	2" BELOW GRASS AND SIDEWALK BEHIND CATCH BASIN.		-122.617693	45.456879	<1000 ADT	19250	20.00	57.02	54.02	159.95	34.02		
34047	9839 SE 43RD AV	MILW	TYP2	WEEK 2		-122.618569	45.451708	>1000 ADT	139485	20.00	86.44	83.44	155.05	63.44	Yes	
34065	4994 SE HARVEY ST	MILW	TYP1			-122.611218	45.451132	<1000 ADT	19305	20.00	57.55	54.55	174.65	34.55		
34074	4813 SE KING RD	MILW	TYP2	WEEK 3		-122.613213	45.448065	>1000 ADT	76314	20.00	58.01	55.01	157.75	35.01		
34095	5510 SE MONROE ST	MILW	TYP2	WEEK 3		-122.606415	45.444635	>1000 ADT	26080	20.00	63.96	60.96	184.27	40.96		
34155	5732 SE LLOYD ST	MILW	TYP1			-122.604203	45.439218	<1000 ADT	20755	20.00	58.13	55.13	160.34	35.13		
34083	4585 SE WHITE LAKE RD	MILW	TYP1			-122.615290	45.449184	<1000 ADT	38490	20.60	61.85	58.85	150.61	38.25		
24024	10112 SE 54TH CT	MILW	TYP1			-122.607246	45.449690	<1000 ADT	7133	21.00	49.96	46.96	182.02	25.96		
34042	9626 SE 49TH AV	MILW	TYP2	WEEK 1		-122.612822	45.453124	>1000 ADT	14157	21.00	53.17	50.17	163.52	29.17		
34050	4345 SE KING RD	MILW	TYP2	WEEK 3		-122.617127	45.448000	>1000 ADT	21092	21.00	68.25	65.25	165.26	44.25		
34068	4479 SE LOGUS RD	MILW	TYP2	WEEK 2		-122.616752	45.450524	>1000 ADT	60284	21.00	71.08	68.08	152.71	47.08		
34136	11576 SE 59TH AV	MILW	TYP2	WEEK 4		-122.601816	45.439943	<1000 ADT	26180	21.00	65.02	62.02	174.27	34.02	Yes	
34168	4404 SE KING RD	MILW	TYP2	WEEK 3		-122.616805	45.447982	>1000 ADT	3978	21.00	68.25	65.25	162.48	44.25		
34125	5092 SE HUNTER CT	MILW	TYP1			-122.610738	45.440379	<1000 ADT	44510	21.30	60.42	57.42	163.27	36.12		
34071	10143 SE 49TH AV	MILW	TYP2	WEEK 2		-122.612623	45.449597	>1000 ADT	36113	21.33	62.05	59.05	173.46	59.05		
34159	4726 SE WASHINGTON PL	MILW	TYP1			-122.613242	45.442880	<1000 ADT	4888	21.33	58.77	55.77	171.37	34.44		
44004	10271 SE 54TH AV	MILW	TYP1			-122.607523	45.449255	<1000 ADT	2004	21.50	54.36	51.36	191.32	29.86		
44005	10271 SE 54TH AV	MILW	TYP1			-122.607526	45.449204	<1000 ADT	2004	21.50	54.36	51.36	192.74	29.86		
34182	5770 SE KING RD	MILW	TYP2	WEEK 3		-122.604260	45.447915	>1000 ADT	33796	21.58	53.36	50.36	186.74	28.78		
34035	9616 SE 43RD AV	MILW	TYP2	WEEK 1 ACTUALLY ON ROCKWOOD AT 44TH COURT, IN THE SIDE (NORTH) YARD OF THIS ADDRESS		-122.617949	45.453664	>1000 ADT	32632	21.80	77.52	74.52	157.42	52.72	Yes	Yes
34180	4314 SE HARRISON ST	MILW	TYP1	ACROSS THE STREET FROM THIS ADDRESS		-122.617728	45.446648	<1000 ADT	2782	21.92	74.68	71.68	184.73	50.57		
34046	9660 SE 43RD AV	MILW	TYP2	WEEK 1		-122.618429	45.452911	>1000 ADT	25062	22.00	88.64	85.64	157.63	65.84	Yes	Yes
34121	4745 SE WASHINGTON PL	MILW	TYP1			-122.613075	45.443283	<1000 ADT	8439	22.00	58.77	55.77	167.07	33.77		
34135	11496 SE 59TH AV	MILW	TYP2	WEEK 4		-122.601738	45.439957	<1000 ADT	18642	22.00	64.77	61.77	174.86	39.77	Yes	
34176	9918 SE 43RD AV	MILW	TYP2	WEEK 2		-122.618401	45.451205	>1000 ADT	3880	22.00	86.44	83.44	155.56	61.44	Yes	
34105	10708 SE HOME AV	MILW	TYP1			-122.611684	45.445803	<1000 ADT	64775	22.08	52.69	49.69	157.79	27.61		
34082	4526 SE WHITE LAKE RD	MILW	TYP1			-122.616210	45.449085	<1000 ADT	17152	22.60	64.31	61.31	152.85	38.71		
34124	4706 SE ADAMS ST	MILW	TYP1			-122.614096	45.442120	<1000 ADT	52161	22.63	64.61	61.61	177.53	39.01		
34179	4314 SE HARRISON ST	MILW	TYP1	ACROSS THE STREET FROM THIS ADDRESS		-122.617760	45.446647	<1000 ADT	2782	22.92	74.68	71.68	185.00	49.57		
34007	4205 SE ROSWELL ST	MILW	TYP1			-122.619615	45.458827	<1000 ADT	43509	23.00	45.37	42.37	150.37	23.04		
34032	4207 SE HARVEY ST	MILW	TYP2	WEEK 2		-122.619517	45.451329	<1000 ADT	80170	23.00	94.96	91.96	162.44	69.96	Yes	
34184	4572 SE KING RD	MILW	TYP2	WEEK 3		-122.615282	45.447952	>1000 ADT	7652	23.00	56.41	53.41	152.01	30.41		
34044	4802 SE ARDEN ST	MILW	TYP1			-122.613710	45.454118	<1000 ADT	58917	23.08	54.94	51.94	161.19	28.86		
34150	5486 SE HARLENE ST	MILW	TYP1			-122.606796	45.442150	<1000 ADT	54778	23.11	59.93	56.93	167.76	33.82		
44001	3206 SE WISTER ST	MILW	TYP1			-122.629706	45.438496	<1000 ADT	58127	23.17	46.38	43.38	0.00	20.21		
24018	5844 SE HARRISON ST	MILW	TYP1			-122.602345	45.446119	<1000 ADT	120923	23.30	57.32	54.32	183.86	31.02		Yes
34031	9738 SE 42ND AV	MILW	TYP2	WEEK 2		-122.620121	45.452766	>1000 ADT	90921	23.30	94.32	91.32	158.49	68.02	Yes	Yes
34058	5123 SE JACKSON ST	MILW	TYP1			-122.610304	45.445861	<1000 ADT	7440	23.50	56.14	53.14	165.31	29.64		
34119	11102 SE 51ST AV	MILW	TYP1			-122.610742	45.443069	<1000 ADT	27970	23.50	53.41	50.41	154.40	26.91		
34183	5880 SE KING RD	MILW	TYP2	WEEK 3		-122.602708	45.447910	>1000 ADT	12744	23.58	48.54	45.54	177.76	21.96		
34033	4243 SE HARVEY ST	MILW	TYP2	WEEK 2		-122.619583	45.450734	<1000 ADT	30834	24.00	91.88	88.88	169.02	64.88	Yes	Yes
34059	4828 SE WILLOW ST	MILW	TYP1			-122.613328	45.452006	<1000 ADT	9452	24.00	57.78	54.78	162.86	30.78		
34102	11003 SE WOOD AV	MILW	TYP1			-122.608715	45.443688	<1000 ADT	36908	24.00	56.03	53.03	164.79	29.03		
34128	11114 SE 60TH AV	MILW	TYP1			-122.600851	45.442936	<1000 ADT	27730	24.00	70.90	67.90	197.39	43.90		Yes
44003	2636 SE GINO LN	MILW	TYP1			-122.635349	45.437784	<1000 ADT	55412	24.00	150.00	9.33	0.00	-9.17		
34076	10508 SE 47TH AV	MILW	TYP1			-122.614255	45.447236	<1000 ADT	70070	24.30	53.07	50.07	151.24	26.07		
34012	8983 SE 41ST AV	MILW	TYP1			-122.621386	45.457590	<1000 ADT	5280	25.00	65.91	62.91	162.31	37.91		
34013	4102 SE WAKE CT	MILW	TYP1			-122.621291	45.456756	<1000 ADT	20956	25.00	69.30	66.30	158.72	41.30		Yes
34051	4345 SE KING RD	MILW	TYP2	WEEK 3		-122.617033	45.448000	>1000 ADT	21092	25.00	68.25	65.25	164.26	40.25		
34084	10317 SE 46TH AV	MILW	TYP1			-122.615136	45.448379	<1000 ADT	280915	25.00	59.16	56.16	149.90	43.96		
34086	3515 SE SHERRY LN	MILW	TYP1			-122.626687	45.452304	<1000 ADT	24206	25.00	92.85	89.85	168.77	64.85		
34138	5866 SE LLOYD ST	MILW	TYP2	WEEK 4		-122.602303	45.439283	<1000 ADT	16747	25.00	61.25	58.25	168.68	33.25	Yes	
34039	4629 SE ROCKWOOD ST	MILW	TYP2			-122.615682	45.453641	>1000 ADT	27331	25.25	67.08	64.08	160.01	38.83		

UIC ID	Address	Owner	Type	Qualifier	Raised	Longitude	Latitude	ADT	Impervious Area (square feet)	UIC Depth	Average Depth to Water (feet)	Seasonal High DTW (feet)	Surface Elevation	Vertical Separation Distance	Within 2 Year Time of Travel	Within 500ft of Private Well
34164	4201 SE MEADOWCREST CT	MILW	TYP1			-122.620048	45.458268	<1000 ADT	2398	25.40	52.15	49.15	155.46	23.75		
34185	4664 SE KING RD	MILW	TYP2	WEEK 3		-122.614809	45.447997	>1000 ADT	3481	25.42	56.41	53.41	4.00	27.99		
34079	10593 SE 47TH AV	MILW	TYP1			-122.614503	45.446623	<1000 ADT	65818	25.50	57.18	54.18	155.39	28.68		
34101	5181 SE MONROE ST	MILW	TYP2	WEEK 3		-122.609417	45.445179	>1000 ADT	41360	25.50	56.35	53.35	167.18	27.85		
34126	11016 SE 60TH AV	MILW	TYP1			-122.600801	45.443664	<1000 ADT	36296	25.58	73.27	70.27	196.78	44.69		
34139	11221 SE LINWOOD AV	MILW	TYP1			-122.599279	45.442087	<1000 ADT	10527	25.92	71.60	68.60	194.92	42.68		Yes
34052	4664 SE KING RD	MILW	TYP2	WEEK 3		-122.614727	45.447945	>1000 ADT	86826	26.00	56.41	53.41	151.23	27.30		
34191	10125 SE HOLLYWOOD AV	MILW		LOC AT SOUTHERN PROPERTY LINE OF ADDRESS, ON HOLLYWOOD		-122.602658	45.448322	<1000 ADT	1790	26.00	45.10	42.10	0.00	42.10		
34192	10144 SE 49TH AV	MILW	TYP2	WEEK 2		-122.612476	45.449444	>1000 ADT	4911	26.00	62.05	59.05	0.00	33.05		
34036	9656 SE 44TH AV	MILW	TYP1			-122.617054	45.453077	<1000 ADT	65144	26.08	73.99	70.99	155.71	44.91		Yes
34148	5225 SE JACKSON ST	MILW	TYP1			-122.609222	45.445762	<1000 ADT	35084	26.11	57.98	54.98	169.25	28.87		
24023	5404 SE LOGUS RD	MILW	TYP2	WEEK 2		-122.607280	45.450387	>1000 ADT	13628	26.20	45.43	42.43	178.84	16.23		
34147	9523 SE 40TH AV	MILW	TYP2			-122.622262	45.454084	<1000 ADT	42701	26.20	92.29	89.29	162.16	63.09	Yes	
34151	9667 SE 49TH AV	MILW	TYP2	WEEK 1		-122.612898	45.453114	>1000 ADT	14153	26.20	53.17	50.17	164.72	23.97		
34107	10750 SE HOME AV	MILW	TYP2	WEEK 3		-122.611737	45.445214	>1000 ADT	9742	26.30	52.80	49.80	156.23	23.50		
24011	9941 SE STANLEY AV	MILW	TYP2	WEEK 2		-122.604662	45.450459	>1000 ADT	80500	26.33	37.79	34.79	169.51	8.46		
34060	4828 SE WILLOW ST	MILW	TYP1			-122.613294	45.452012	<1000 ADT	9453	26.58	57.78	54.78	162.92	28.20		
34040	4813 SE ROCKWOOD ST	MILW	TYP2	WEEK 1		-122.613502	45.453246	>1000 ADT	18255	27.00	57.59	54.59	162.36	27.59		
34077	10593 SE 47TH AV	MILW	TYP1			-122.614407	45.446726	<1000 ADT	65818	27.00	57.18	54.18	153.10	27.18		
34110	10722 SE 55TH AV	MILW	TYP1			-122.606658	45.444787	<1000 ADT	25752	27.00	63.34	60.34	182.14	35.64		
34173	9712 SE 46TH AV	MILW	TYP1			-122.615370	45.452817	<1000 ADT	26926	27.00	68.78	65.78	161.20	38.78		
34027	9405 SE 42ND AV	MILW	TYP2	WEEK 1 NEED FLAGGERS FOR CLEANING		-122.620217	45.454567	>1000 ADT	150788	27.20	81.94	78.94	156.61	51.74	Yes	
34088	10236 SE 41ST CT	MILW	TYP1	CUP MEDALLION		-122.620227	45.449127	<1000 ADT	27720	27.42	91.44	88.44	186.77	61.02		Yes
34098	5464 SE WOODHAVEN ST	MILW	TYP1			-122.606691	45.443018	<1000 ADT	36177	27.67	59.03	56.03	171.15	28.36		
34075	10463 SE 47TH AV	MILW	TYP1			-122.614412	45.447576	<1000 ADT	70069	28.00	56.56	53.56	149.61	26.56		
34090	10527 SE 44TH AV	MILW	TYP1	ACTUALLY ON HARRISON, SOUTH EAST OF PROPERTY LISTED		-122.617093	45.446666	<1000 ADT	144511	28.00	69.80	66.80	179.34	38.80		
34029	9475 SE 40TH AV	MILW	TYP1	WEEK 1		-122.622262	45.454301	>1000 ADT	50464	28.11	92.29	89.29	161.16	61.18	Yes	
34023	3739 SE OLSEN ST	MILW	TYP2	WEEK 1		-122.623664	45.454860	>1000 ADT	39900	28.17	87.00	84.00	160.58	55.83		
34122	4705 SE WASHINGTON ST	MILW	TYP2	WEEK 4		-122.614004	45.443034	>1000 ADT	4142	28.30	62.34	59.34	174.26	31.04		
34106	4993 SE MONROE ST	MILW	TYP2			-122.612120	45.445195	>1000 ADT	11047	28.33	52.80	49.80	154.91	21.47		
34061	9827 SE 49TH AV	MILW	TYP2	WEEK 1		-122.612599	45.452162	>1000 ADT	58253	28.43	57.78	54.78	166.03	26.35		
34145	11192 SE 52ND CT	MILW	TYP1			-122.610641	45.442345	<1000 ADT	32823	29.00	54.53	51.53	153.17	22.53		
44002	11855 SE 32ND AV	MILW	TYP1	UNDER LOW HANGING POWER LINES, HARD TO CLEAN		-122.630365	45.437804	<1000 ADT	9070	29.00	43.07	40.07	0.00	11.07		
34112	11104 SE HOME AV	MILW	TYP2	WEEK 4		-122.611879	45.442887	>1000 ADT	25752	29.10	56.53	53.53	164.07	24.43		
34009	8954 SE 43RD AV	MILW	TYP1			-122.618415	45.458294	<1000 ADT	45987	29.20	50.71	47.71	158.31	18.51		
34022	4710 SE FIELDCREST DR	MILW	TYP1			-122.614666	45.454906	<1000 ADT	40200	29.42	55.17	52.17	157.83	22.75		
24021	5838 SE MONROE ST	MILW	TYP2	WEEK 3		-122.602094	45.444602	>1000 ADT	33809	29.50	69.81	66.81	201.98	37.31		Yes
34030	9631 SE 42ND AV	MILW	TYP2	WEEK 1		-122.620212	45.453502	>1000 ADT	24907	29.50	95.29	92.29	157.09	62.79	Yes	Yes
34070	4705 SE LOGUS RD	MILW	TYP2	WEEK 2 IN BARKDUST, BEHIND BUSHES		-122.614700	45.450534	>1000 ADT	60284	29.50	66.25	63.25	160.89	33.75		
34024	3739 SE OLSEN ST	MILW	TYP2	WEEK 1		-122.623687	45.454804	>1000 ADT	39900	29.58	87.00	84.00	161.01	54.42		
34008	8929 SE 42ND AV	MILW	TYP2	WEEK 1 ON ROSWELL		-122.620391	45.458527	>1000 ADT	127501	29.80	55.38	52.38	153.26	22.58		
34099	11015 SE 54TH AV	MILW	TYP1			-122.607545	45.443130	<1000 ADT	32356	29.92	59.03	56.03	165.84	26.11		
34067	9907 SE 48TH AV	MILW	TYP1	DRYWELL IS DEEPER THAN 30 FT, BUT ONLY HAVE ENOUGH TUBES ON VACTOR TO CLEAN TO 30 FT.		-122.613772	45.451270	<1000 ADT	41711	30.00	63.32	60.32	163.17	30.32		
34169	4545 SE GARRETT CR	MILW	TYP1			-122.615460	45.444339	<1000 ADT	19250	30.00	64.98	61.98	177.59	31.98		
34111	11017 SE HOME AV	MILW	TYP2	WEEK 4		-122.611828	45.443344	>1000 ADT	25752	30.30	56.53	53.53	161.08	23.23		
34127	11002 SE 60TH AV	MILW	TYP1			-122.600687	45.443603	<1000 ADT	36296	30.30	70.05	67.05	198.03	36.75		
34113	11104 SE HOME AV	MILW	TYP2	WEEK 4		-122.611889	45.442819	>1000 ADT	25751	30.67	56.53	53.53	164.45	22.86		
34011	4764 SE LOGUS RD	MILW	TYP2	WEEK 2		-122.613959	45.450456	>1000 ADT	45987	31.00	63.76	60.76	164.81	29.76		
34143	11262 SE 48TH CT	MILW	TYP1			-122.613042	45.441649	<1000 ADT	9282	31.20	62.36	59.36	170.98	28.16		
34156	4645 SE WASHINGTON ST	MILW	TYP2	WEEK 4		-122.614146	45.443012	>1000 ADT	9522	31.20	62.34	59.34	173.74	28.14		
34103	11003 SE WOOD AV	MILW	TYP1			-122.608724	45.443595	<1000 ADT	36911	31.42	56.03	53.03	164.46	21.61		
24014	10294 SE 36TH AV	MILW	TYP1			-122.625985	45.448940	<1000 ADT	76621	31.90	77.49	74.49	165.06	46.91		
34114	11112 SE HOME AV	MILW	TYP2	WEEK 4		-122.611908	45.442662	>1000 ADT	25751	32.00	58.52	55.52	164.73	23.52		
34116	5001 SE PARK ST	MILW	TYP2	WEEK 4 AT INTERSECTION; ON HOME AVE		-122.611876	45.441437	>1000 ADT	31706	32.00	61.14	58.14	168.30	26.14		
34080	4751 SE HARRISON ST	MILW	TYP1			-122.613844	45.446570	<1000 ADT	65818	32.08	53.37	50.37	152.29	18.29		
34140	4341 SE ROCKWOOD ST	MILW	TYP1	DRYWELL IS ACTUALLY IN 44TH CT TO THE WEST OF ADDRESS		-122.617924	45.453945	<1000 ADT	9957	32.60	74.81	71.81	155.43	39.21	Yes	Yes
34144	11192 SE 52ND CT	MILW	TYP1			-122.610651	45.442388	<1000 ADT	32818	32.60	54.53	51.53	153.04	18.93		
24013	5206 SE LOGUS RD	MILW	TYP2	WEEK 2		-122.609425	45.450420	>1000 ADT	28338	33.30	51.73	48.73	177.33	15.43		
24003	3898 SE WAKE ST	MILW	TYP1	BUIRED		-122.622767	45.456873	<1000 ADT	34442	33.50	70.19	67.19	158.22	33.69		
34045	9665 SE 43RD AV	MILW	TYP2	WEEK 1		-122.618559	45.452972	>1000 ADT	26500	33.50	88.64	85.64	157.32	52.14	Yes	Yes
34115	11134 SE HOME AV	MILW	TYP2	WEEK 4		-122.611900	45.442533	>1000 ADT	25751	33.60	58.52	55.52	165.37	21.92		

Attachment A

UIC Preliminary System-Wide Assessment

City of Milwaukie, Oregon

UIC ID	Address	Owner	Type	Qualifier	Raised	Longitude	Latitude	ADT	Impervious Area (square feet)	UIC Depth	Average Depth to Water (feet)	Seasonal High DTW (feet)	Surface Elevation	Vertical Separation Distance	Within 2 Year Time of Travel	Within 500ft of Private Well
24010	10256 SE 38TH AV	MILW	TYP1			-122.623405	45.449253	<1000 ADT	46214	33.70	88.81	85.81	176.37	52.11		
34049	4215 SE KING RD	MILW	TYP2	WEEK 3		-122.618615	45.448037	>1000 ADT	5250	33.83	81.83	78.83	183.37	44.83		
24004	9040 SE 39TH AV	MILW	TYP1	BEHIND CURB IN DIRT		-122.622550	45.456916	<1000 ADT	34442	34.00	70.19	67.19	159.16	33.19		
34087	10205 SE 41ST CT	MILW	TYP1	CUP MEDALLION		-122.621115	45.449139	<1000 ADT	27719	34.00	94.83	91.83	187.93	57.83		Yes
34091	10477 SE 53RD PL	MILW	TYP1			-122.608009	45.447590	<1000 ADT	19673	34.00	63.94	60.94	192.18	26.94		
34092	10592 SE 55TH AV	MILW	TYP1			-122.606600	45.446406	>1000 ADT	29467	34.30	68.46	65.46	193.15	31.16		
34048	10360 SE 43RD AV	MILW	TYP2	WEEK 3		-122.618476	45.448429	>1000 ADT	9227	34.70	83.03	80.03	175.48	45.33		
24015	10229 SE 38TH AV	MILW	TYP1			-122.623579	45.449099	<1000 ADT	93384	35.00	88.81	85.81	176.37	50.81		
34108	4993 SE MONROE ST	MILW	TYP2	WEEK 3		-122.612229	45.445201	>1000 ADT	21816	35.00	52.80	49.80	154.78	14.80		
34034	4341 SE ROCKWOOD ST	MILW	TYP2	WEEK 1		-122.617913	45.453768	<1000 ADT	32632	35.50	77.52	74.52	156.02	39.02	Yes	Yes
34109	4972 SE MONROE ST	MILW	TYP2	WEEK 3 APPROX. 15' SOUTH OF PHONE POLE ON EAST SIDE OF FENCE		-122.611966	45.445032	>1000 ADT	25751	35.50	52.80	49.80	154.90	14.30		
24012	5621 SE LOGUS RD	MILW	TYP2	WEEK 2		-122.606137	45.450463	>1000 ADT	12094	36.00	42.18	39.18	174.07	3.18		
34094	10722 SE 55TH AV	MILW	TYP1			-122.606657	45.444829	<1000 ADT	13853	36.50	63.34	60.34	182.02	36.24		
Inactive UICs																
34028	4200 SE COVELL ST	MILW	TYP1	DECOMMISSIONED		-122.619851	45.454648	<1000 ADT	21105	0.00	80.24	77.24	155.78	77.24		
34153	11800 SE STANLEY AV	MILW		WAS A WEEK 4 THIS IS NOW A SEDIMENTATION MANHOLE. DRYWELL RECORDS SAVED. 31055 IS CURRENT MANHOLE NUMBER		-122.602973	45.438233		60571	5.67	58.33	2.00	159.65	0.00	Yes	Yes
34041	4813 SE ROCKWOOD ST	MILW	TYP2	NOT RAISED. UNDER DRIVEWAY BEHIND CATCH BASIN.	Not Rasied	-122.613509	45.453297	>1000 ADT	18255	0.00	57.59	54.59	162.64	54.59		
24028	10425 SE 42ND AV	MILW	TYP2	DISCONNECTED BUT NOT DECOM'D		-122.619663	45.447985	>1000 ADT	0	0.00	86.33	83.33	189.25	83.33		
34017	4207 SE FIELDCREST AV	MILW	TYP1	NOT RAISED DISCONNECTED BUT NOT DECOM'D	Not Rasied	-122.619674	45.455548	<1000 ADT	15340	0.00	75.06	72.06	159.01	72.06		Yes
34026	9393 SE 42ND AV	MILW	TYP2	NOT RAISED UNDER CONCRETE DRIVEWAY, DISCONNECTED	Not Rasied	-122.620296	45.454856	>1000 ADT	46261	0.00	81.94	78.94	156.59	78.94		Yes
34123	11121 SE 47TH AV	MILW	TYP2	NOT RAISED DISCONNECTED BUT NOT DECOM'D	Not Rasied	-122.614276	45.442962	>1000 ADT	63181	0.00	62.34	59.34	173.63	59.34		
34174	4645 SE WASHINGTON ST	MILW	TYP2	NOT RAISED DISCONNECTED FROM SYSTEM	Not Rasied	-122.614186	45.443072	>1000 ADT	22406	0.00	62.34	59.34	172.83	59.34		
24026	3305 SE MARY CT	MILW	TYP1	DISCONNECTED BUT NOT DECOMMISSIONED (HOME OWNER SOMETIMES BURRIES)		-122.628875	45.460196	<1000 ADT	24273	13.40	54.36	51.36	145.49	37.96		
34018	4212 SE FIELDCREST	MILW	TYP1	RAISED AND DISCONNECTED, NOT DECOM'D		-122.619679	45.455437	<1000 ADT	15340	22.00	75.06	72.06	159.06	50.06		Yes
34005	8731 SE 40TH AV	MILW	TYP2	DISCONNECTED BUT NOT DECOM'D		-122.622076	45.459456	>1000 ADT	29601	23.00	46.39	43.39	150.96	20.39		
34006	8685 SE 41ST AV	MILW	TYP1	DISCONNECTED BUT NOT DECOM'D		-122.621149	45.460202	<1000 ADT	78921	24.50	43.25	40.25	148.93	15.75		
34004	8731 SE 40TH AV	MILW	TYP2	DISCONNECTED BUT NOT DECOM'D		-122.622073	45.459526	>1000 ADT	29599	30.60	46.39	43.39	151.18	12.79		
34003	8731 SE 40TH AV	MILW	TYP2	DISCONNECTED BUT NOT DECOM'D		-122.622077	45.459506	>1000 ADT	29599	33.50	46.39	43.39	151.11	9.89		

Notes

WET FEET UICs
DRY FEET UICs WITH < 1.0 FEET SEPARATION DISTANCE

ADT = Average Daily Trips

UIC = Underground Injection Control

DTW = Depth to Water

Attachment B – Technical Documentation for the Unsaturated Zone GWPD

1 Pollutant Fate and Transport Processes

An Underground Injection Control (UIC) device allows stormwater to infiltrate into the unsaturated zone (i.e., variably saturated soils above the water table). The stormwater is transported downward by matric forces that hold the water close to mineral grain surfaces. During transport, pollutant concentrations are attenuated by the following processes:

- **Volatilization.** Volatilization is pollutant attenuation by transfer from the dissolved phase to the vapor phase. Because soil pores in the unsaturated zone are only partially filled with water, chemicals with a high vapor pressure volatilize into the vapor phase. The propensity of a pollutant to volatilize is described by the Henry's constant. Because volatilization is not significant at depths below most UIC bottoms (USEPA, 2001), volatilization is not included in the unsaturated zone Groundwater Protectiveness Demonstration (GWPD).

- **Adsorption.** Adsorption is pollutant attenuation by partitioning of substances in the liquid phase onto the surface of a solid substrate. Physical adsorption is caused mainly by Van der Waals forces and electrostatic forces between the pollutant molecule and the ions of the solid substrate molecule's surface. For organic pollutants, the unsaturated zone GWPD simulates adsorption is a function of f_{oc} (fraction organic compound) and K_{oc} (organic carbon partitioning coefficient). For metals, the unsaturated zone GWPD uses stormwater analytical data to estimate adsorption.

- **Degradation.** Degradation is pollutant attenuation by biotic and abiotic processes. Abiotic degradation includes hydrolysis, oxidation-reduction, and photolysis. Biotic degradation involves microorganisms metabolizing pollutants through biochemical reactions.

- **Dispersion.** Dispersion describes pollutant attenuation from pore water mixing, which occurs because of differences in subsurface permeability.

2 Pollutant Fate and Transport Input Parameters

The unsaturated zone GWPD consists of an analytical model that simulates the effects of adsorption, degradation, and dispersion based on user-specified input parameters from selected references and available regulatory guidance. Input parameters to the unsaturated zone GWPD model include soil properties, organic carbon content in the subsurface, and pollutant properties, as described in the following sections:

- Soil properties
  - Total porosity and effective porosity (Section 2.1.1)
  - Soil bulk density (Section 2.1.2)
  - Dispersion coefficient and dispersivity (Section 2.1.3)
  - Average linear pore water velocity (Section 2.1.4)
- Organic carbon content of the subsurface
  - Fraction organic carbon (Section 2.2.1)
- Pollutant properties
  - Organic carbon partitioning coefficient (Section 2.3.1)
  - Distribution coefficient (Section 2.3.2)
  - Degradation rate constant and half life (Section 2.3.3)
  - Retardation factor (Section 2.3.4)

2.1 Soil Properties

Soil properties include total porosity, effective porosity, soil bulk density, dispersivity/dispersion coefficient, and average linear pore water velocity.

2.1.1 Total Porosity (η) and Effective Porosity (η_e)

Total porosity is the percent of pore space in a material. Porosities are correlated with soil type (e.g., sand, silt, gravel), and were estimated from Table 2.4 of Freeze and Cherry (1979). Specifically, the midrage porosity was used. Effective porosity is the percent of pore space through which flow occurs, as was estimated as 0.31 for the USA hydrogeologic unit from USGS (2008)

2.1.2 Soil Bulk Density (ρ_b)

Bulk density is the density of a soil, including soil particles and pore space. According to Freeze and Cherry (1979), bulk density is calculated from total porosity by the following formula:

$$\rho_b = 2.65(1-\eta) \tag{B.1}$$

2.1.3 Dispersion Coefficient (D) and Dispersivity (α)

Dispersion is the spreading of a pollutant plume caused by differential advection. The dispersion coefficient, D, is defined as:

$$D = \alpha\ v \tag{B.2}$$

where:

v is average linear pore water velocity (L/T), and
α is longitudinal dispersivity (L).

The dispersivity (and therefore the dispersion coefficient) is a scale-dependent parameter. According to a review of tracer tests conducted under saturated conditions, dispersivity is estimated as (Gelhar et al., 1992):

$$\alpha \leq \frac{L}{10} \tag{B.3}$$

where:

L is the length scale of transport (i.e., separation distance) (L).

However, according to a review of tracer tests conducted in the unsaturated zone, dispersivity can be significantly less than would be estimated by Equation (B.3) (Gehlar et al., 1985):

$$\frac{L}{10} \leq \alpha \leq \frac{L}{100} \tag{B.4}$$

Because the unsaturated zone under the UICs is at near-saturated conditions, this technical memorandum assumes that $\alpha_L = \frac{L}{20}$, which is less than saturated dispersivity, but is on the high end of the reported range in unsaturated dispersivity.

2.1.4 Average Linear Pore Water Velocity (v)

Average linear pore water velocity is the rate that water moves vertically through the unsaturated zone, and is directly proportional to soil moisture content (i.e., pore water velocity increases as soil moisture content increases). Soil moisture content is the percent of water in soil, and is equal to or less than porosity. The unsaturated zone GWPD conservatively assumes that soils are fully saturated, which is likely representative of actual conditions because of the near-constant infiltration of water during the rainy season.

Darcy's Law is (Stephens, 1996):

$$v = -K_u\left(\frac{\partial \psi}{\partial y} + \frac{\partial y}{\partial y}\right) \tag{B.5}$$

where:

v is specific discharge (L/T),
K_u is unsaturated hydraulic conductivity (L/T), estimated from infiltration tests,
$\left(\frac{\partial \psi}{\partial y}\right)$ is the pressure gradient (L/L), and
$\left(\frac{\partial y}{\partial y}\right)$ is the head gradient (L/L).

In the unsaturated zone, $\left(\frac{\partial y}{\partial y}\right)$ = 1. When the unsaturated zone is stratified and pressure head is averaged over many layers (which is the case in Portland Basin sediments), $\left(\frac{\partial \psi}{\partial y}\right)$ = 0. Under these conditions, equation (B.5) reduces to (Stephens, 1996):

$$v = -K_u \tag{B.6}$$

Average linear pore water velocity is calculated by dividing Equation B.6 by 0.31, the effective porosity of the USA hydrogeologic unit (USGS, 2008).

2.2 Organic Carbon Content in the Subsurface

The organic carbon content in the subsurface is parameterized by fraction organic carbon, a dimensionless measure of the quantity of organic carbon in soil (i.e., g_{carbon} / g_{soil}). Carbon in unsaturated soil beneath a UIC is derived from two sources:

- Organic carbon incorporated into sediments during deposition
- Particulate matter (e.g., degraded leaves, pine needles, pollen, etc.) that is filtered out of stormwater and accumulates in unsaturated soil adjacent to UICs as stormwater discharges from the UIC

Organic carbon incorporated into the Portland Basin sediments (i.e., Missoula Flood Deposits) during deposition is relatively low; therefore, the unsaturated zone GWPD only considers organic carbon that accumulates in the unsaturated zone soils due to filtering of particulate matter in stormwater.

2.2.1 Fraction Organic Carbon (f_{oc})

Stormwater contains organic carbon from degraded leaves, pine needles, pollen, etc. As stormwater infiltrates into the unsaturated zone surrounding the UIC, the organic carbon is filtered out of solution and the f_{oc} in soil increases over time because of the ongoing addition of organic carbon. An estimate of f_{oc} based on the accumulation of carbon in unsaturated soil was derived by calculating the grams of organic carbon added to unsaturated materials surrounding the UIC during a 10-year period. A 10-year accumulation period was selected because literature evaluating the longevity of organic material in bioretention cells indicates that it lasts about 20 years before it begins to degrade (Weiss et al, 2008). The following equations were used in the analysis:

$$I = (A)(p)(1-e) \qquad \text{(B.7)}$$

$$CL = (I)(C)(t)\left(\frac{1\,\text{liter}}{1{,}000\,\text{cm}^3}\right)\left(\frac{1\,\text{gram}}{1{,}000\ \text{milligrams}}\right) \qquad \text{(B.8)}$$

$$\rho_{oc} = \frac{CL}{SV} \qquad \text{(B.9)}$$

$$f_{oc} = \frac{\rho_{oc}}{\rho_b + \rho_{oc}} \qquad \text{(B.10)}$$

where:

I	=	Average annual stormwater infiltration volume (cubic feet per year)
A	=	Area of a typical UIC catchment (square feet)
p	=	Precipitation (feet per year)
e	=	Evaporative loss fraction (dimensionless)
CL	=	Organic carbon loaded into the unsaturated zone beneath a UIC during a 10-year period (grams)

C = TOC concentration in stormwater (milligrams per liter)
t = Time of carbon loading (years)
ρ_{oc} = Organic carbon weight per unit unsaturated zone material volume (grams per cubic centimeter)
SV = Material volume into which the organic carbon would accumulate because of filtration and adsorption (assumed to be the volume of soil from 3 feet above the UIC bottom to 5 feet below the base of the UIC, extending 1 foot from the radius of the UIC) (cubic centimeters)
f_{oc} = Fraction organic carbon (dimensionless)
ρ_b = Bulk density (grams per cubic centimeter)

Calculations of f_{oc}, based on the filtering of TOC for the average and reasonable maximum scenarios, are shown in Tables B-1 through B-4. First, the average annual precipitation was calculated from rain gages (Table B-1) and used to calculate the volume of stormwater that infiltrates into a UIC (Table B-2) by Equation (B.7). Next, a time-weighted average total organic carbon concentration in stormwater was calculated (Table B-3) and was used to calculate the grams of carbon added to the unsaturated zone surrounding the UIC during a 10-year period by Equation (B.8), mass of organic carbon per unit volume of material surrounding the UIC (ρ_{oc}) by Equation (B.9), and convert ρ_{oc} to f_{oc} by Equation (B.10) (Table B-4).

2.3 Pollutant Properties

Pollutant properties include the organic carbon partitioning coefficient, distribution coefficient, degradation rate constant/half life, and retardation factor.

2.3.1 Organic Carbon Partitioning Coefficient (K_{oc})

The organic carbon partitioning coefficient (K_{oc}) is pollutant specific, and governs the degree to which the pollutant will partition between the organic carbon and water phases. Higher K_{oc} values indicate that the pollutant has a higher tendency to partition in the organic carbon phase, and lower K_{oc} values indicate that the pollutant will have a higher tendency to partition in the water phase.

K_{oc} was assigned differently for PCP and other organic pollutants, according to the following criteria:

- **PCP.** The K_{oc} for PCP is pH dependent, so K_{oc}s for the average and reasonable maximum scenarios were estimated on the basis of the range of groundwater pH of shallow groundwater.

- **All Organic Pollutants except PCP.** For the average scenario, K_{oc} was estimated from empirical regression equations relating K_{oc} to the octanol water partitioning coefficient (K_{ow}) and/or pollutant solubility. For the reasonable maximum scenario, K_{oc} was assumed to be either the lowest-reported literature value or the K_{oc} calculated by empirical equations, which ever was lower (i.e., more conservative).

2.3.2 Distribution Coefficient (K_d)

For organic pollutants, the distribution coefficient, K_d, was estimated from the following equation (e.g., Watts, 1998):

$$K_d = f_{oc} K_{oc} \tag{B.11}$$

For metals, K_d was estimated from equations in Bricker (1998). The most important solid phases for sorption of metals in environmental porous media are clays, organic matter, and iron/manganese oxyhydroxides (Langmuir et al., 2004). The distribution of a trace metal between dissolved and sorbed phases is described by the following equation:

$$K_d = \frac{C_s}{C_w} \tag{B.12}$$

where:

C_s is the concentration of the metal adsorbed on the solid phase (M/L^3), and
C_w is the dissolved concentration (M/L^3).

The value of K_d for metals can depend on a number of environmental factors, including the nature and abundance of the sorbing solid phases, dissolved metal concentration, pH, redox conditions, and water chemistry. Measured K_d values for a given metal range over several orders of magnitude depending on the environmental conditions (Allison and Allison, 2005). Therefore, site-specific K_d values are preferred for metals over literature-reported K_ds. K_d values can be determined empirically for a particular situation from Equation (B.12) (Bricker, 1998). The partitioning coefficients were estimated from total and dissolved metals concentrations and total suspended solids (TSS) data. Sorbed concentrations were calculated by normalizing the particulate metals concentrations to the concentration of TSS. For each sample, an apparent K_d value was calculated for each metal from the following equation:

$$K_d = \frac{\left([Me]_t - [Me]_d\right)}{[Me]_d \times TSS} \times 10^6 \tag{B.13}$$

where:

$[Me]_t$ is total metals concentration (M/L^3), and
$[Me]_d$ is dissolved metal concentration (M/L^3)

Note that in Equation (B.13), metals concentrations are in micrograms per liter, and TSS are in units of milligrams per liter.

Although the K_ds are determined from systems containing lower concentrations of sorbing particle surfaces than is typical of stormwater infiltrating through a soil column, this is considered to be conservative because (1) the low levels of suspended solids in the stormwater may result in nonlinear sorption regime, in which case calculated K_d values may be significantly lower than would be expected in a higher surface area environment (i.e., the unsaturated zone), and (2) site-specific K_ds calculated in the stormwater already account for the effect of dissolved organic carbon, which could lower apparent K_d values by complexing with trace metals, and thereby shifting the partitioning to the solution.

2.3.3 Degradation Rate Constant (*k*) and Half Life (*h*)

Degradation rate is a chemical-specific, first-order rate constant, and depends on whether the unsaturated zone is aerobic or anaerobic. The organic pollutants evaluated in the unsaturated zone GWPD are biodegradable under aerobic conditions (Aronson et al., 1999; MacKay, 2006); therefore, it is expected that these compounds will biodegrade to some extent within the unsaturated zone after discharging from the UIC. Metals are not included in this section because they do not undergo biodegradation.

Aerobic biodegradation rate constants were compiled from a review of the scientific literature, including general reference guides as well as compound-specific studies. The review included degradation in soils, surface water, groundwater, and sediment. Soil aerobic degradation rates were considered to be most representative of UIC field conditions and these are summarized for each of the compounds of interest. First-order rate constants are generally appropriate for describing biodegradation under conditions where the substrate is limited and there is no growth of the microbial population (reaction rate is dependent on substrate concentration rather than microbial growth). Because of the low concentrations of the organic pollutants detected in stormwater, it is appropriate to consider biodegradation as a pseudo-first-order rate process for the UIC unsaturated zone scenario.

The ranges of biodegradation rates representative of conditions expected to be encountered in the unsaturated zone beneath UICs are summarized in Table B-5. Summary statistics provided in Table B-5 include number of measurements, minimum, maximum, mean, 25th, and 50th percentile (median) values. For the average scenario, the median biodegradation rate was used. For the reasonable maximum, the 25th percentile biodegradation rate was used.

The half-life of a pollutant is the time required for pollutant concentration decline to one half of its initial value. Half-life is calculated by the following formula:

$$h = \frac{\ln(2)}{k} \qquad \text{(B.14)}$$

where:

k is the first-order rate constant (T^{-1}), and
h is the half-life (T)

2.3.4 Retardation Factor (*R*)

The retardation factor, *R*, is the ratio between the rate of pollutant movement and the rate of pore water movement. For example, a retardation factor of 2 indicates that pollutants move twice as slow as pore water. The retardation factor is estimated by equation 9.14 of Freeze and Cherry (1979):

$$R = 1 + \frac{(\rho_b)(K_d)}{\eta} \qquad \text{(B.15)}$$

where:

ρ_b is soil bulk density (M/L^3),
K_{oc} is the organic carbon partitioning coefficient (L^3/M),
f_{oc} is fraction organic carbon (dimensionless), and
η is total porosity (dimensionless).

3 Governing Equation for Unsaturated Zone GWPD

A one-dimensional pollutant fate and transport equation was used to estimate the magnitude of pollutant attenuation during transport through the unsaturated zone. This constant source Advection-Dispersion Equation (ADE) incorporates adsorption, degradation (biotic and abiotic), and dispersion to estimate pollutant concentration at the water table (e.g., Watts, 1998). This equation is provided below:

$$\frac{C(y,t)}{C_0} = \frac{1}{2}\left[\left(e^{A_1}\right) erfc\left(A_2\right) + \left(e^{B_1}\right) erfc\left(B_2\right)\right] \tag{B.16}$$

where:

$$A_1 = \left(\frac{y}{2D'}\right)\left(v' - \sqrt{(v')^2 + 4D'k'}\right)$$

$$A_2 = \frac{y - t\sqrt{(v')^2 + 4D'k'}}{2\sqrt{D't}}$$

$$B_1 = \left(\frac{y}{2D'}\right)\left(v' + \sqrt{(v')^2 + 4D'k'}\right)$$

$$B_2 = \frac{y + t\sqrt{(v')^2 + 4D'k'}}{2\sqrt{D't}}$$

$$v' = \frac{v}{R}$$

$$D' = \frac{D}{R}$$

$$k' = \frac{k}{R}$$

and:

y is distance in the vertical direction (L),
v is average linear pore water velocity (L/T),
D is the dispersion coefficient (L^2/T),
R is the retardation factor (dimensionless),
k is the first-order degradation constant (T^{-1}),
t is average infiltration time (T),
C_0 is initial pollutant concentration (M/L^3),
$C(y, t)$ is pollutant concentration at depth y and time t (M/L^3), and
erfc is complementary error function used in partial differential equations

Equation (1) is an exact solution to the one-dimensional ADE. The exact solution can be used for both short (i.e., less than 3.5 meters) and long transport distances (greater than 35 meters; Neville and Vlassopoulos, 2008). An approximate solution to the 1-dimensional ADE has also been developed, and can only be used for long transport distances. The unsaturated zone GWPD uses the exact solution to the ADE.

With the exception of infiltration time (t), the input parameters were described in Section 2. Infiltration time is the length of time during the year that stormwater discharges into a UIC and, therefore, migrates downward through the unsaturated zone. For modeling purposes, the duration of the rainy season is estimated to be 7 months. Because stormwater discharges into UICs only when the precipitation rate exceeds a threshold value, the infiltration time is dependent on the occurrence of rain events equal to or greater than this amount. The DEQ (2005) permit fact sheet for the City of Portland assigns a threshold precipitation rate of 0.08 inch/hour for stormwater to discharge into UICs. The unsaturated zone GWPD conservatively assumes that stormwater discharges into UICs at one-half of the threshold precipitation rate (i.e., 0.04 inch/hour). Precipitation and infiltration times from 1999 to 2011 in the City are shown in Table B-1.

The key assumptions in applying this equation include:

- Transport is one-dimensional vertically downward from the bottom of the UIC to the water table (Note: water typically exfiltrates from holes in the side of the UIC, as well as from the bottom).
- The stormwater discharge rate into the UIC is constant and maintains a constant head within the UIC to drive the water into the unsaturated soil. (Note: stormwater flows are highly variable, short duration, and result in varying water levels within the UIC dependent on the infiltration capacity of the formation.)
- Pollutant concentrations in water discharging into the UIC are uniform and constant throughout the period of infiltration (Note: concentrations are variable seasonally and throughout storm events).
- The pollutant undergoes equilibrium sorption (instantaneous and reversible) following a linear sorption isotherm.
- The pollutant is assumed to undergo a first-order transformation reaction involving biotic degradation.
- The pollutant does not undergo transformation reactions in the sorbed phase (i.e., no abiotic or biotic degradation).
- There is no portioning of the pollutant to the gas phase in the unsaturated zone.
- The soil is initially devoid of the pollutant.

The unsaturated zone GWPD provides a conservative simulation of pollutant fate and transport for the following reasons:

- Modern UICs are constructed with a solid concrete bottom so stormwater is discharged horizontally through the sides of the UIC at up to 20 feet above the bottom of the UIC and then migrates vertically downward. Thus, the assumption that stormwater flows vertically downward from the base of the UIC underestimates the travel distance of stormwater in the unsaturated zone.

- Stormwater flow from the UIC is assumed to be constant with a uniform flow through the unsaturated zone, while in reality stormwater flows are highly variable and short in duration resulting in varying water levels within the UIC depending on the infiltration capacity of the formation. Thus, the UIC periodically will fill with water and then drain. This will cause variable flow from the UIC. It is not feasible to simulate complex cycles of filling and drainage for each UIC. Thus, the simplified approach is implemented in which the analytical solution is used to predict concentrations at a time corresponding to the period over which the UIC likely contains water. This approach is conservative because it predicts the maximum infiltration that would be expected at the water table sustained for the period during which the UIC contains water.

- Pollutant concentrations are assumed to be constant, while in reality they are variable throughout storm events. This likely over-predicts the concentration throughout the duration of a storm event. In addition, the unsaturated zone GWPD does not take into account pollutant attenuation that occurs while in the UIC (i.e. through adsorption to sediment or organic matter in the UIC) before entering the surrounding soil.

4 Infiltration Tests for Calculating Average Linear Pore Water Velocity

Infiltration tests are conducted to estimate hydraulic conductivity (a proportionality constant that, under unsaturated conditions, is equivalent to specific discharge [see Equation B.5]). Pump-in tests consist of injecting water into a UIC at a known rate until the water level in the UIC stabilizes. Figure B-1 shows a conceptual diagram of a UIC during a pump-in test.

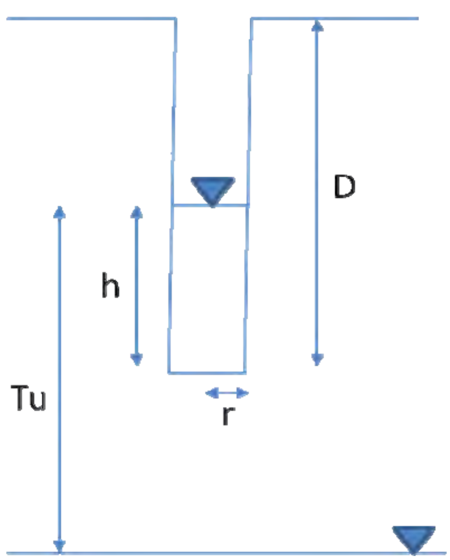

Figure B-1. Pump-in test conceptual model.

According to USDI (1993), horizontal hydraulic conductivity in the unsaturated zone is calculated from a pump-in test by the following formulae:

$K_s =$

$$\frac{\left[\ln\left(\frac{h}{r}+\sqrt{\left(\frac{h}{r}\right)^{2}+1}\right)-1\right]Q}{2\pi h^{2}} \quad \text{if } T_u \geq 3h \tag{B.17}$$

$$\left[\frac{3\ln\left(\frac{h}{r}\right)}{\pi h\left(h+2T_U\right)}\right]Q \quad \text{if } 3h \geq T_u \geq h \tag{B.18}$$

where:

K_s is saturated hydraulic conductivity (L/T),

h is the height of the stable water level above the UIC bottom (L),

D is the depth of the UIC from ground surface to bottom (L)

T_u is the separation distance between the water table and stable water level in the UIC (L),

Q is the rate water enters the UIC when the water level is stable (L^3/T), and

r is the radius of the UIC (L).

In the unsaturated zone beneath UICs, specific discharge is equivalent to unsaturated hydraulic conductivity (K_u). However, the fate and transport analysis uses saturated hydraulic conductivity (K_s) in Equation (B.5) to calculate groundwater velocity. Because of the tortuosity of unsaturated flow paths, K_u is always smaller than K_s (usually by several orders of magnitude); therefore, using K_s in Equation (B.5) is conservative. Because water is transported vertically through the unsaturated zone, the horizontal hydraulic conductivity calculated by the pump-in test must be converted to a vertical hydraulic conductivity.

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Table B-1

Precipitation, 1999 - 2011

City of Milwaukie, Oregon

Year	Precipitation (inches)	Precipitation (feet)	Hours With ≥ 0.04 inches/hr intensity (hours)	Days with ≥ 0.04 inches/hr intensity (days)
2011	47.40	4.0	441	18.4
2010	53.73	4.5	482	20.1
2009	33.14	2.8	303	12.6
2008	32.12	2.7	283	11.8
2007	38.89	3.2	389	16.2
2006	44.40	3.7	417	17.4
2005	33.55	2.8	291	12.1
2004	28.32	2.4	249	10.4
2003	38.96	3.2	378	15.8
2002	30.55	2.5	284	11.8
2001	31.24	2.6	299	12.5
2000	24.06	2.0	227	9.5
1999	36.72	3.1	352	14.7
Maximum	*53.73*	*4.48*	*482*	*20.1*
Minimum	*24.06*	*2.01*	*227*	*9.5*
Average	*36.39*	*3.03*	*338*	*14.1*
Median	*33.55*	*2.80*	*303*	*12.6*
Geomean	*35.57*	*2.96*	*330*	*13.7*

Notes

Data from Harney Street Rain Gage at 2033 SE Harney Street, available online at the City of Portland HYDRA Rainfall Network: http://or.water.usgs.gov/non-usgs/bes/

Table B-2

Stormwater Infiltration Volume

City of Milwaukie, Oregon

Impervious Area, *A* (ft^2)	**Annual Precipitation, *P*** (Geometric Mean, 1999 - 2011) (ft/yr)	**Evaporative Loss Factor, *e*** (-)	**Infiltration Volume, *I*** (ft^3/year)	**Infiltration Volume, *I*** (cm^3/yr)
36,225 (1)	2.96	0.26 (2)	79,468 (3)	2.25E+09 (3)

Notes

(1) Average impervious area based on delineations for 194 UIC drainage basins in the City of Milwaukie.

(2) Evaporation Loss Factor from Snyder and otehrs (1994)

(3) Calculated by the following equation: $I = (A)(P)(1\text{-}e)$

ft = feet

cm = centimeters

Table B-3

Total Organic Carbon in Stormwater

City of Milwaukie, Oregon

		TOC Concentrations				Average Scenario (calculated using mean TOC)			Reasonable Maximum Scenario (calculated using minimum TOC)		
Time Period	Months	N	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Weighting		Weighted Mean TOC (mg/L)	Weighting		Weighted Mean TOC (mg/L)
Fall	Oct, Nov (1)	15	3.1	55.4	20.5	2 / 9	22%	8.19	2 / 9	22%	1.44
Winter	Dec, Jan, Feb, Mar (2)	61	0.25	9.7	2.5	4 / 9	44%		4 / 9	44%	
Spring	Apr, May, June (3)	27	1.9	23.8	7.6	3 / 9	33%		3 / 9	33%	

Notes

(1) Data from Clackamas County WES

(2) Data from City of Gresham

(3) Data from City of Portland and City of Milwaukie

mg/L = milligrams per liter

Table B-4

Fraction Organic Carbon

City of Milwaukie, Oregon

	CL Calculation					*SV Calculation*					ρ_{oc} *Calculation*	f_{oc} Calculation	
	Infiltration Volume (cm^3/yr)	**Carbon Concentration** (mg TOC/1000 cm^3)	**Time** (years)	**Conversion Factor for ug to g**	**CL**	**UIC radius** (cm)	**UIC radius + 1 foot** (cm)	**3' Above base volume** (cm^3)	**5' Below base volume** (cm^3)	**Total Volume** (cm^3)	ρ_{oc} (g TOC per cm^3 soil)	**Bulk Density** (g/cm^3)	f_{oc}
Average Scenario	2.25E+09	8.19	10	1,000,000	184,195	60.96	91.44	1,333,723	4001170.42	5,334,894	0.034526425	1.66	0.020375
Reasonable Maximum Scenario	2.25E+09	1.44	10	1,000,000	32,404	60.96	91.44	1,333,723	4001170.42	5,334,894	0.006073976	1.66	0.003646

Notes

cm = centimeters

mg = milligrams

ug = micrograms

g = grams

yr = year

Equations:

$$CL = (I)(C)(t)\left(\frac{1\text{ liter}}{1{,}000\text{ cm}^3}\right)\left(\frac{1\text{ gram}}{1{,}000\ \text{ milligrams}}\right)$$

$$\rho_{oc} = \frac{CL}{SV}$$

$$f_{oc} = \frac{\rho_{oc}}{\rho_b + \rho_{oc}}$$

CL = Organic carbon loaded into the unsaturated zone beneath a UIC during a 10-year period

I = Average annual stormwater infiltration volume

C = TOC concentration in stormwater

t = time of carbon loading

ρ_{oc} = Organic carbon weight per unit unsaturated zone material volume

SV = material volume into which the organic carbon would accumulate because of filtration and adsorption (assumed to be the soil from three feet above the UIC bottom to five feet below the base of the UIC, extending 1 foot from the radius of the UIC (equation not shown)

f_{oc} = fraction organic carbon

ρ_b = bulk density

Table B-5

Biodegradation Rates

City of Milwaukie, Oregon

Compound	First-Order Biodegradation Rate (day^{-1})					
	N	*Median*	*Mean*	*Maximum*	*25 th percentile*	*Minimum*
Benzo(a)pyrene [1]	38	0.0013	0.0021	0.015	0.00026	ND
Di-(2-ethylhexyl)phthalate [2]	34	0.015	0.021	0.082	0.01	0.004
PCP [3]	10	0.206	0.221	0.361	0.1695	0.139

Notes:

[1] Rate constants under aerobic conditions in soil were compiled from Aronson et al. (1999) Ashok et al. (1995); Bossart and Bartha (1986); Carmichael and Pfaender (1997); Coover and Sims (1987); Deschenes et al. (1996); Grosser et al. (1991); Grosser et al. (1995); Howard et al. (1991); Keck et al. (1989); Mackay et al. (2006); Mueller et al. (1991); Park et al. (1990); and Wild and Jones (1993).

[2] From Dorfler et al. (1996); Efroymson and Alexander (1994); Fairbanks et al. (1985); Fogel et al. (1995); Maag and Loekke (1990); Mayer and Sanders (1973); Ruedel et al. (1993); Schmitzer et al. (1988); Scheunert et al. (1987) and Shanker et al. (1985).

[3] From Schmidt et al. (1999) and D'Angelo and Reddy (2000)

Attachment C

Table C-1. Pollutant Fate and Transport

Groundwater Protectiveness Demonstration

	Parameter	Symbol	Units	Metals		PAHs		SVOCs			
				Lead		Benzo(a)pyrene		PCP		di-(2-ethylhexyl) phthalate	
				Average Scenario	Reasonable Maximum Scenario	Average Scenario	Reasonable Maximum Scenario	Average Scenario	Reasonable Maximum Scenario	Average Scenario	Reasonable Maximum Scenario
UIC Properties	Distance Needed to Reach MRLs	y	m	0.00283	0.0130	0.00044	0.0079	0.14	2.85	0.0090	0.1589
		y	ft	0.00929	0.043	0.00145	0.02586	0.47	9.34	0.029	0.52
	Concentration	C_0	mg/L	0.50 [1]	0.50 [1]	0.002 [1]	0.002 [1]	0.01 [1]	0.01 [1]	0.06 [1]	0.06 [1]
	Infiltration Time	t	d	13,750 [2]	13,750 [2]	13.75 [3]	13.75 [3]	13.75 [3]	13.75 [3]	13.75 [3]	13.75 [3]
Pollutant Properties	First-Order Rate Constant	k	d^{-1}			1.30E-03 [4]	2.60E-04 [5]	2.21E-02 [6]	1.39E-02 [7]	1.50E-02 [4]	1.00E-02 [5]
	Half-Life	h	d			533.2 [8]	2666.0 [8]	31.4 [8]	49.9 [8]	46.2 [8]	69.3 [8]
Physical and Chemical Soil Properties	Soil Porosity	η	-	0.375 [9]	0.375 [9]	0.375 [9]	0.375 [9]	0.375 [9]	0.375 [9]	0.375 [9]	0.375 [9]
	Soil Bulk density	ρ_b	g/cm^3	1.66 [10]	1.66 [10]	1.66 [10]	1.66 [10]	1.66 [10]	1.66 [10]	1.66 [10]	1.66 [10]
	Fraction Organic Carbon	f_{oc}	-			0.0208 [11]	0.0024 [11]	0.0208 [11]	0.0024 [11]	0.0208 [11]	0.0024 [11]
	Organic Carbon Partition Coefficient	K_{oc}	L/kg			282,185 [12]	282,185 [12, 13]	877 [14]	703 [14]	12,200 [12]	12,200 [12, 13]
	Distribution Coefficient	K_d	L/kg	1,203,704 [15]	535,040 [16]	5,872 [17]	674 [17]	18.3 [17]	1.7 [17]	253.9 [17]	29.2 [17]
	Pore Water Velocity	v	m/d	0.37 [18]	0.75 [19]	0.37 [18]	0.75 [19]	0.37 [18]	0.75 [19]	0.37 [18]	0.75 [19]
Calculations	Retardation Factor	R	-	5,316,360	2,363,094	25,937	2,980	81.6	8.4	1,122	130
	Dispersion Coefficient	D	m^2/d	5.16E-05	4.85E-04	8.09E-06	2.94E-04	2.63E-03	1.06E-01	1.64E-04	5.93E-03
	Normalized Dispersion	D'	m^2/d	9.71E-12	2.05E-10	3.12E-10	9.87E-08	3.22E-05	1.26E-02	1.46E-07	4.57E-05
	Normalized Velocity	v'	m/d	6.87E-08	3.16E-07	1.41E-05	2.50E-04	4.47E-03	8.86E-02	3.25E-04	5.75E-03
	Normalized Degradation	k'	d^{-1}	0.00E+00	0.00E+00	5.01E-08	8.73E-08	2.71E-04	1.65E-03	1.34E-05	7.71E-05
	A_1	-	-	0.00E+00	0.00E+00	-1.58E-06	-2.75E-06	-8.71E-03	-5.29E-02	-3.69E-04	-2.13E-03
	A_2	-	-	2.58E+00	2.58E+00	1.91E+00	1.91E+00	1.96E+00	1.95E+00	1.59E+00	1.59E+00
	e^{A1}	-	-	1.00E+00	1.00E+00	1.00E+00	1.00E+00	9.91E-01	9.48E-01	1.00E+00	9.98E-01
	$erfc(A_2)$	-	-	2.63E-04	2.63E-04	7.03E-03	7.04E-03	5.62E-03	5.89E-03	2.42E-02	2.43E-02
	B_1	-	-	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.01E+01	2.00E+01	2.00E+01
	B_2	-	-	5.16E+00	5.16E+00	4.86E+00	4.86E+00	4.88E+00	4.89E+00	4.75E+00	4.75E+00
	e^{B1}	-	-	4.85E+08	4.85E+08	4.85E+08	4.85E+08	4.89E+08	5.12E+08	4.85E+08	4.86E+08
	$erfc(B_2)$	-	-	2.84E-13	2.84E-13	6.20E-12	6.20E-12	4.96E-12	4.73E-12	1.89E-11	1.89E-11
	Concentration Immediately Above Water Table	C	mg/L	1.00E-04	1.00E-04	1.00E-05	1.00E-05	4.00E-05	4.00E-05	1.00E-03	1.00E-03
MRL		C	mg/L	1.00E-04	1.00E-04	1.00E-05	1.00E-05	4.00E-05	4.00E-05	1.00E-03	1.00E-03
Action Level		C	mg/L	5.00E-01 [20]		2.00E-03 [20]		1.00E-02 [20]		6.00E-02 [20]	

NOTES *(SEE APPENDIX B FOR CITATIONS)*

[1] Equal to the action level in Table 1 or Table 2 of the July 2012 draft UIC WPCF permit template

[2] Infiltration time for lead is 1,000 years (1,000 years at 13.75 days per year = 13,750 days)

[3] Infiltration time is the number of hours (converted to days) during the year that stormwater infiltrates into the UIC. Stormwater infiltration is conservatively assumed to occur when the precipitation rate is $\geq$ 0.04 inches/hour. Precipitation data source is the Harney Street rain gage at 2033 SE Harney Street (HYDRA, 2012). Annual precipitation from 1999 to 2011 were used in the analysis, and were averaged using the geometric mean.

[4] Median biodegradation rate from a review of scientific literature (see Table B-5 for references).

[5] 25th percentile biodegradation rate from a review of scientific literature (seeTable B-5 for references).

[6] 10 percent of the average biodegradation rate of PCP under aerobic conditions (see Table B-5 for references).

[7] 10 percent of the minimum biodegradation rate of PCP under aerobic conditions (see Table B-5 for references).

[8] Calculated from the following formula: $C_t = C_0e^{-kt}$, where C_t is concentration at time t, C_0 is initial concentration, t is time, and k is biodegradation rate.

[9] Madin (1990) identifies the Qff as a coarse sand to silt. Therefore, the midrange porosity of a sand from Freeze and Cherry (1979), page 37, Table 2.4 is used in this analysis (range = 0.25 to 0.50).

[10] Calculated by formula 8.26 in Freeze and Cherry (1979): $\rho_b = 2.65(1-\eta)$.

[11] Estimate of f_{oc} based on loading of TOC in stormwater; see Appendix B for details.

[12] Calculated from the equation of Roy and Griffin (1985), which relates K_{oc} (soil organic carbon-water partitioning coefficient) to water solubility and K_{ow} (octanol-water partitioning coefficient) as presented in Fetter (1994).

[13] Because the K_{oc}s reported in field studies were all higher than K_{oc}s calculated from K_{ow} (i.e., field-study K_{oc}s were less conservative), the reasonable maximum scenario uses the K_{oc} calculated by Roy and Griffin (1985)

[14] The K_{oc} for Pentachlorophenol is pH-dependent. Soil and groundwater pH are in equilibrium; therefore, soil pH can be estimated from groundwater pH. Ph has been measured at twelve USGS wells screened at or near the water table in Portland on the east side of the Willamette River from 1997 to 2007. The average groundwater pH at the wells is 6.4, and was used for the "Average Scenario". This pH is consistent with shallow soil pH in Multnomah County (Green, 1983). The PCP organic carbon partitioning coefficient when pH = 6.4 is 877 L/kg [EPA (1996) – Appendix L: Koc Values for Ionizing Organics as a Function of pH]. Because PCP is more mobile at higher pH, Koc for the "Reasonable Maximum Scenario" is based on the average maximum groundwater pH at the USGS wells (i.e., 6.6). This pH is consistent with shallow soil pH in Multnomah County (Green, 1983). The PCP organic carbon partitioning coefficient when pH = 6.6 is 704 L/kg.

[15] Median K_d for lead, calculated using stormwater analytical data collected by the City of Milwaukie in spring of 2012 and an equation from Brickner (1998)

[16] 10th percentile K_d for lead, calculated using stormwater analytical data collected by the City of Milwaukie in spring of 2012 and an equation from Brickner (1998)

[17] K_d calculated from the following equation: $Kd = (f_{oc})(K_{oc})$ (e.g., Watts, pg. 279, 1998).

[18] The median average linear velocity calculated using the pump-in method at11 City of Milwaukie UICs. The pump-in method is outlined in USDI (pgs. 83 - 95, 1993).

[19] The 95% UCL on the mean of average linear velocity based on 11 pump-in tests at City of Milwaukie UICs. The pump-in method is outlined in USDI (pgs. 83 - 95, 1993). 95% UCL was calculated using ProUCL Software Version 4.00.05 and the 95% Student's-t UCL.

[20] Action Levels from Table 1 and Table 2 of the July 2012 draft UIC WPCF permit template.

ABBREVIATIONS

PAHs = Polynuclear Aromatic Hydrocarbons
SVOCs = Semi-Volatile Organic Compounds
VOCs = Volatile Organic Compounds
PCP = Pentachlorophenol
USGS = United States Geological Survey
UCL = Upper Confidence Level
MRL = Method Reporting Limit
UIC = Underground Injection Control
WPCF = Water Pollution Control Facilities
Qmf = Quaternary Missoula Flood Deposits
EPA = Environmental Protection Agency
TOC = Total Organic Carbon
d = days
g/cm^3 = grams per cubic centimeter
ft = feet
L = Liters per kilogram
m = meters
m/d = meters per day
m^2/d = square meters per day
mg/L = milligrams per liter

Attachment C
Table C-2. Pollutant Fate and Transport
Alternate Action Levels

	Parameter	Symbol	Units	Metals						SVOCs	
				Zinc		Copper		Antimony		di-(2-ethylhexyl) phthalate	
				Average Scenario	Reasonable Maximum Scenario	Average Scenario	Reasonable Maximum Scenario	Average Scenario	Reasonable Maximum Scenario	Average Scenario	Reasonable Maximum Scenario
UIC Properties	Transport Distance	y	m	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
		y	ft	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Concentration	C_0	mg/L	50.0 [1]	50.0 [1]	10.0 [1]	10.0 [1]	0.060 [1]	0.060 [1]	0.30 [1]	0.30 [1]
	Infiltration Time	t	d	13,750 [2]	13,750 [2]	13,750 [2]	13,750 [2]	13,750 [2]	13,750 [2]	13.75 [3]	13.75 [3]
Pollutant Properties	First-Order Rate Constant	k	d^{-1}							1.50E-02 [4]	1.00E-02 [5]
	Half-Life	h	d							46.2 [6]	69.3 [6]
Physical and Chemical Soil Properties	Soil Porosity	η	-	0.375 [7]	0.375 [7]	0.375 [7]	0.375 [7]	0.375 [7]	0.375 [7]	0.375 [7]	0.375 [7]
	Soil Bulk density	ρ_b	g/cm^3	1.66 [8]	1.66 [8]	1.66 [8]	1.66 [8]	1.66 [8]	1.66 [8]	1.66 [8]	1.66 [8]
	Fraction Organic Carbon	f_{oc}	-							0.0208 [9]	0.0024 [9]
	Organic Carbon Partition Coefficient	K_{oc}	L/kg							12,200 [10]	12,200 [10,11]
	Distribution Coefficient	K_d	L/kg	53,263 [12]	22,542 [13]	159,310 [14]	24,801 [15]	24,927 [12]	9,675 [13]	253.9 [16]	29.2 [16]
	Pore Water Velocity	v	m/d	0.37 [17]	0.75 [18]	0.37 [17]	0.75 [18]	0.37 [17]	0.75 [18]	0.37 [17]	0.75 [18]
Calculations	Retardation Factor	R	-	235,246	99,562	703,620	109,539	110,095	42,732	1,122	130
	Dispersion Coefficient	D	m^2/d	5.57E-03	1.14E-02	5.57E-03	1.14E-02	5.57E-03	1.14E-02	5.57E-03	1.14E-02
	Normalized Dispersion	D'	m^2/d	2.37E-08	1.14E-07	7.91E-09	1.04E-07	5.06E-08	2.66E-07	4.96E-06	8.77E-05
	Normalized Velocity	v'	m/d	1.55E-06	7.49E-06	5.19E-07	6.81E-06	3.32E-06	1.75E-05	3.25E-04	5.75E-03
	Normalized Degradation	k'	d^{-1}	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.34E-05	7.71E-05
	A_1	-	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.25E-02	-4.09E-03
	A_2	-	-	7.86E+00	2.55E+00	1.43E+01	2.80E+00	4.92E+00	5.37E-01	1.82E+01	3.25E+00
	e^{A1}	-	-	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	9.88E-01	9.96E-01
	$erfc(A_2)$	-	-	9.98E-29	3.15E-04	1.08E-90	7.66E-05	3.47E-12	4.48E-01	5.03E-146	4.19E-06
	B_1	-	-	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01	2.00E+01
	B_2	-	-	9.05E+00	5.15E+00	1.50E+01	5.27E+00	6.65E+00	4.50E+00	1.87E+01	5.53E+00
	e^{B1}	-	-	4.85E+08	4.85E+08	4.85E+08	4.85E+08	4.85E+08	4.85E+08	4.91E+08	4.87E+08
	$erfc(B_2)$	-	-	1.79E-37	3.37E-13	2.13E-99	8.70E-14	5.34E-21	1.89E-10	9.82E-155	5.18E-15
	Concentration Immediately Above Water Table	C	mg/L	4.67E-27	1.19E-02	1.06E-89	5.94E-04	1.82E-13	1.62E-02	1.47E-146	1.00E-06
MRL		C	mg/L	5.00E-04	5.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-03	1.00E-03
Action Level		C	mg/L	5.00E+00 [19]		5.00E-03 [19]		6.00E-03 [19]		6.00E-02 [19]	

NOTES *(SEE APPENDIX B FOR CITATIONS)*

[1] Equal to the 10X the action level in Table 1 of the July 2012 draft UIC WPCF permit template for zinc, antimony, copper, and cadmium; equal to 5X the action level in Table 1 for DEHP.

[2] Infiltration time for metals is for 1,000 years (1,000 years at 13.75 days per year = 13,750 days)

[3] Infiltration time is the number of hours during the year (converted to days) that stormwater infiltrates into the UIC. Stormwater infiltration is conservatively assumed to occur when the precipitation rate is ≥ 0.04 inches/hour. Precipitation data source is the Harney Street rain gage at 2033 SE Harney Street (HYDRA, 2012). Annual precipitation from 1999 to 2011 were used in the analysis, and were averaged using the geometric mean.

[4] Median biodegradation rate from a review of scientific literature (see Table B-5 for references).

[5] 25th percentile biodegradation rate from a review of scientific literature (see Table B-5 for references).

[6] Calculated from the following formula: $C_t = C_0e^{-kt}$, where C_t is concentration at time t, C_0 is initial concentration, t is time, and k is biodegradation rate.

[7] Madin (1990) identifies the Qff as a coarse sand to silt. Therefore, the midrange porosity of a sand from Freeze and Cherry (1979), page 37, Table 2.4 is used in this analysis (range = 0.25 to 0.50).

[8] Calculated by formula 8.26 in Freeze and Cherry (1979): $\rho_b = 2.65(1-\eta)$.

[9] Estimate of f_{oc} based on loading of TOC in stormwater; see Appendix B for details.

[10] Calculated from the equation of Roy and Griffin (1985), which relates K_{oc} (soil organic carbon-water partitioning coefficient) to water solubility and K_{ow} (octanol-water partitioning coefficient) as presented in Fetter (1994).

[11] Because the K_{oc}s reported in field studies were all higher than K_{oc}s calculated from K_{ow} (i.e., field-study K_{oc}s were less conservative), the reasonable maximum scenario uses the K_{oc} calculated by Roy and Griffin (1985)

[12] Median K_d, calculated using stormwater discharge monitoring data from the City of Portland and an equation from Brickner (1998)

[13] 10th percentile K_d, calculated using stormwater discharge monitoring data from the City of Portland and an equation from Brickner (1998)

[14] Median K_d for copper, calculated using stormwater analytical data collected by the City of Milwaukie in spring of 2012 and an equation from Brickner (1998)

[15] 10th percentile K_d for copper, calculated using stormwater analytical data collected by the City of Milwaukie in spring of 2012 and an equation from Brickner (1998)

[16] K_d calculated from the following equation: $Kd = (f_{oc})(K_{oc})$ (e.g., Watts, pg. 279, 1998).

[17] The median average linear velocity calculated using the pump-in method at 11 City of Milwaukie UICs. The pump-in method is outlined in USDI (pgs. 83 - 95, 1993).

[18] The 95% UCL on the mean of average linear velocity based on 11 pump-in tests at City of Milwaukie UICs. The pump-in method is outlined in USDI (pgs. 83 - 95, 1993). 95% UCL was calculated using ProUCL Software Version 4.00.05 and the 95% Student's-t UCL.

[19] Action Levels from Table 1 and Table 2 of the July 2012 draft UIC WPCF permit template.

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PCP	= Pentachlorophenol
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Qmf	= Quaternary Missoula Flood Deposits
EPA	= Environmental Protection Agency
TOC	= Total Organic Carbon
d	= days
g/cm^3	= grams per cubic centimeter
ft	= feet
L	= Liters per kilogram
m	= meters
m/d	= meters per day
m^2/d	= square meters per day
mg/L	= milligrams per liter