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**The effects of utility pole placement and characteristics on
pentachlorophenol concentrations entering Underground Injection Control (UIC)
devices: City of Gresham, Oregon**

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In partial fulfillment of the requirements of the Masters of Environmental Management Degree
Portland State University, June 2012

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ABSTRACT

Urbanization is causing increased amounts of stormwater runoff, while simultaneously decreasing the amount of pervious surface area for infiltration. Multiple priority pollutants have been identified in urban stormwater, including pentachlorophenol (PCP). PCP is often found in stormwater samples exceeding the Safe Drinking Water Act limit of 1µg/L and can cause human health issues with exposure over time. Treated wood utility poles are the major source of PCP in urban stormwater. With the use of underground injection control (UIC) devices as an alternative method to treat and dispose of stormwater, the potential exists for groundwater contamination of PCP. The City of Gresham currently owns and operates approximately 1,100 UIC devices.

In this study 60 UIC device contributing areas were surveyed for the presence and characteristics of utility poles. A positive correlation was found between utility pole surface area in a UIC contributing area and PCP concentration in stormwater. A stronger correlation exists for surface area of utility poles surrounded by concrete and PCP concentration in stormwater. The year of the last inspection by the electrical company could also be an indicator of PCP concentration in stormwater, as additional treatment compound is often injected into utility poles during these inspections. The intensity of the rainfall event during stormwater sample collection, in combination with these other attributes, may impact how much treatment compound is able to leach from the pole. Recommendations for future work include adding to the sample set of PCP concentrations for multiple UIC sites and using GoogleEarth to identify utility poles surrounded by concrete in other UIC contributing areas.

INTRODUCTION

Increasing urbanization has led to increased stormwater runoff and less infiltration of precipitation through pervious surfaces for groundwater recharge (Pitt et al., 1999). Griffin, et al. (1980) found that watershed imperviousness influences pollutant loads in stormwater runoff and reports dating back to the late 1980s to Congress identify urban stormwater runoff as one of the leading causes of water quality impairment of rivers, lakes, and estuaries (USEPA, 1990). Modeling studies have predicted that runoff volumes will continue to increase as cities grow and replace pervious surfaces with impervious areas (Sloto, 1998). Drywells, or underground injection control (UIC) devices, are one type of stormwater infiltration contraptions used in urban areas to reduce stormwater runoff to surface water bodies and direct it to the subsurface (Pitt et al., 1999).

Urban stormwater runoff can vary in both quantity and quality depending on the rainfall volume, intensity, antecedent conditions. Traffic patterns, landuse, regional hydrogeology, and street maintenance can also impact the runoff quality (Tsihrintzis & Hamid, 1997). Contaminants commonly found in stormwater runoff include heavy metals, nutrients, pesticides and herbicides, volatile organic compounds, salts, and pathogens (Pitt et al., 1999). Because runoff has the potential to contain many more pollutants than when precipitation was just falling on pervious areas, there is also a greater potential for these pollutants to reach groundwater sources when runoff is directed to a UIC device.

The City of Gresham has approximately 1,100 underground injection control (UIC) devices, primarily located in the Columbia Slough and Fairview Creek watersheds where there are large areas with porous soils (*FIGURE 1*) (Gresham, 2007). These wells, defined by the US

Environmental Protection Agency (USEPA) as “a well completed above the water table so that its bottom and sides are typically dry except when receiving fluids,” are used to manage stormwater by infiltrating it into the subsurface rather than flowing directly into waterways.

Pentachlorophenol (PCP), also known as penta or PCP, is a priority pollutant in urban stormwater and is designated a toxic pollutant in Section 307(a)(1) of the Clean Water Act (33 USC § 1251). It is widely used as an industrial wood preservative and has been known to extend the life of utility poles from seven years to an average of thirty-five (Wilkinson, 1979; Roche, 1965). Historically, PCP was used as a commercial and residential herbicide, defoliant, mossicide, and disinfectant. However due to discovered adverse human health effects and its toxicity to aquatic organisms, the EPA restricted all non-industrial or residential uses of pentachlorophenol in 1987 (USEPA). The USEPA has set a maximum contaminant level of 0.001 mg/L for pentachlorophenol in drinking water (USEPA).

In a early EPA investigation of urban stormwater runoff, Cole et al. (1984) found that PCP was detected in stormwater samples from five of nineteen participating cities and 15% of samples contained PCP ranging from 1-115µg/L. While broadly used in the timber industry worldwide for the past 50 years (Mills, et al. 2006) on such products as utility poles, railroad ties, and wood crates (Christodoulatos, 1994), most urban areas contain an abundance of PCP treated utility poles. These poles are known to leach PCP and can contaminate surrounding soils and groundwater (Christodoulatos, 1994). Given the continuing development in Gresham, the City is challenged to identify which pollutants are of primary concern and the source or sources of those pollutants.

Figure 1. Gresham city limits showing location of the five watersheds. The blue dots represent the approximately 1,100 UIC devices and the red dots represent the 60 random and spatially balanced sample points used in this study and the 2009-2010 Wet Weather Study (Gresham, 2009). The majority of UIC devices are located in the Fairview Creek and Columbia Slough watersheds.

Underground Injection Control (UIC) Device & WPCF Permit Background

The USEPA categorizes UIC devices into five classes, with stormwater drainage wells falling into Class V. These are shallow wells that depend on gravity to inject non-hazardous

fluids, typically runoff from impervious surfaces, directly underground (40 CFR 144.80). A typical UIC device configuration is shown in *FIGURE 2*. Stormwater is collected in the catch basin inlet from the impervious surface, possibly diverted to a sedimentation manhole, and infiltrates into the subsurface once it reaches the UIC. Pre-treatment devices include sumped catch basins and sedimentation manholes, which restrict sediment-bound pollutants from reaching the UIC device. They theoretically reduce the amount of maintenance required on UIC devices since less debris is reaching the UIC. These best management practices for UIC devices are most successful with regular maintenance and cleaning (ACWA, 2003).

DEQ recommends a vertical separation distance from the bottom of the UIC device to the seasonal high water table of 7-10 feet in coarse-grained soils (DEQ). In Gresham, the depth of the UICs range from about fifteen to thirty feet, with the majority in the range of 20 feet. There is typically a minimum of 10 feet of vertical separation between the bottom of the UIC and the local groundwater table (T. Lindbo, personal communication). Additionally, under the UIC rule authorization requirements in the Oregon Administrative Rules (OAR) Division 44, DEQ requires that a UIC device is no closer than 500 feet to a domestic drinking water well and a two year travel time or 500 feet to a public drinking water well, whichever is more protective. Additionally, the UIC should be located in soils such that it can fully drain 48 hours after a storm event (ACWA, 2003). There are exemptions for older wells that do not meet these requirements under a municipal UIC WPCF permit, however all newly constructed UIC devices in Gresham must meet the rule authorization requirements (Gresham, 2011a).

Figure 2. Typical layout of a UIC device. In Gresham, the pretreatment device may be sumped catch basin, sedimentation manhole, or both. From *Underground Injection Control Wells Best Management Practices*, Oregon Association of Clean Water Agencies, 2003.

Congress passed the Safe Drinking Water Act (SDWA) in the 1970s, granting the USEPA the authority to regulate UIC devices in order to protect freshwater aquifers from contamination. The Underground Injection Control Program was created and regulations were initially passed in the early 1980s to define the five well classes and set minimum standards. In 1984 the State of Oregon was delegated the authority by the USEPA to administer the UIC permit program under the title 40 of the Code of Federal Regulations (CFR) parts 144-146 (USEPA). The federal regulations were updated in 1999 and DEQ released OAR 340-044 in September 2001. OAR 340-044-0018 includes special reporting and registration requirements for municipalities with greater than 50 UIC devices.

In 1999, the USEPA estimated that there were approximately 248,000 stormwater drainage wells in the United States, while only approximately 77,000 wells were documented. About 6% of the documented wells were located in Oregon (USEPA, 1999). In 2005 ODEQ issued its only WPCF/UIC area-wide permit (Permit #102830) to the City of Portland for their approximately 9,900 UICs (DEQ). The City of Gresham is currently in the process of obtaining a WPCF permit from DEQ.

The State of Oregon has identified groundwater as a critical natural resource that must be protected for future beneficial uses. It has also determined that once polluted, groundwater can be quite difficult and sometimes impossible to clean. As such, the Oregon Administrative Rule (OAR) 340-040 provides minimum groundwater protection standards to assure that groundwater remains at a quality acceptable for human consumption and the WPCF permit requires that UIC systems adhere to these regulations (DEQ).

Pentachlorophenol Background

Pentachlorophenol, a fungicide used in the wood preservative industry, has a chemical formula of C_6HCl_5O and a molecular weight of 266.34. The solubility of pentachlorophenol is dependent on temperature and pH, with solubility increasing with increasing temperature and pH. The pKa is 4.75 (Christodoulatos 1994).

Technical grade PCP, which is most commonly used on wooden utility poles, is typically a grey or brown color and contains 85-90% PCP, 5-12% tetrachlorophenol and other polychlorophenols, and traces of other polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (Choudhury et.al, 1986). The poles are generally pressure treated with a mixture

of PCP in heavy oil, allowing the mixture to coat the cell walls inside the wood matrix and protect the pole from rotting and decay (Wilkinson 1979, Christodoulatos et al 1994).

Utility poles are inspected approximately every ten years by performing a density test. If it is found that the pole has a hollow heart or bug infestation, it will either be treated by injecting additional pentachlorophenol solution into the wood matrix or will be replaced, depending on the damage (PGE, personal communication). During a visual inspection of utility poles, it is easy to determine if additional pentachlorophenol has been injected into the pole by the presence of wood or plastic diffusion plugs.

Studies have demonstrated that aqueous solutions of PCP can be degraded through microbial processes and photolysis (Wong & Crosby, 1981; Pignatello et.al 1983). The rate at which the PCP degrades from absorbing ultraviolet radiation is dependent on the pH of the solution as well as the depth of the water. For example, Wong & Crosby (1981) found that at pH 7.3 the half life of the PCP solution was 3.5 hours while at pH 3.3 the half life was approximately 100 hours. Pignatello et.al (1983) found that degradation decreased with increased stream depth, as less light is able to penetrate from the surface. PCP also adsorbs to soil particles in the subsurface. Sorption is greater at lower temperatures and pH and when soil contains greater amounts of fines and organic carbon (Christodoulatos et al., 1994)

Exposure to even low levels of PCP over a long period of time can result in liver or kidney damage and other problems with the immune system (USEPA). These effects could be compounded by other chemicals present in technical grade PCP. When there is exposure to high levels of PCP, fever and difficulty breathing can occur (ODHS, 2006). There may be an increased risk of cancer with exposure to high levels of PCP (USEPA). Some animals, when

exposed to high levels, had increased nasal, endocrine, and liver tumors (ODHS, 2006). Tests also show that it is teratogenic and fetotoxic in rats (Cole et al., 1984).

Previous Investigations

1) Kennedy/Jenks Report (2009)

In 2009 the Oregon Association of Clean Water Agencies (ACWA) contracted Kennedy/Jenks Consultants to compile and analyze stormwater data from 25,247 samples provided by 15 Oregon public agencies. 45 analytes were analyzed from five major chemical groups: metals, phenols, phthalates, polynuclear aromatic hydrocarbons, and nutrients. Not all samples were analyzed for all of the analytes. The goal of the study was to determine which pollutants were prevalent above ODEQ screening levels for the UIC program and if high levels of pollutants were correlated with the number of vehicle trips per day or adjacent land uses. The City of Gresham was one of the public agencies involved in the contract (Kennedy/Jenks, 2009).

Of the 675 samples tested for PCP in the study, Kennedy/Jenks found that 11.7% exceeded the screening level of 1 µg/L as stated in both the EPA Drinking Water Maximum Contaminant Level and the DEQ Drywell Compliance Maximum Allowable Discharge Level (MADLs from Portland's WPCF permit). The third screening level used in the study, the Oregon Administrative Rule Numerical Groundwater Reference Level (OAR-340-0020) did not have a screening level for PCP. In fact, PCP was one of only three analytes to exceed one or more screening levels in more than 1% of samples (Kennedy/Jenks, 2009).

Due to the relatively high percentage of non-compliant samples, PCP was one of five analytes used in the study statistical analysis to explore the relationship between stormwater

pollutants and number of vehicle trips per day or land use in the area the sample was collected from. The other analytes used in the analysis were lead, nitrate-nitrogen (NO₃-N), Bis(2-ethylhexyl) phthalate (DEHP), and benzo(a)pyrene (B(a)P). The analysis determined that PCP concentration found in stormwater from streets with greater than 1,000 trips per day was significantly higher ($\alpha = 0.05$) than stormwater from streets with less than 1,000 trips per day. It also determined that PCP concentrations were significantly higher ($\alpha = 0.05$) in commercial and industrial land uses than in residential land uses, although there were not significant differences between commercial and industrial land uses. In general, the report determined that vehicle trips per day is potentially a better indicator of stormwater quality than surrounding land use (Kennedy/Jenks, 2009).

2) City of Gresham UIC Priority Pollutant Wet Weather Study (2009-2010)

The City of Gresham conducted an exploratory study of stormwater samples from 60 UIC devices during December 2010 – February 2011 in order to better understand stormwater characteristics in Gresham and to compare those characteristics to stormwater data from the City of Portland. The Generalized Random Tessellation Stratified (GRTS) survey design (Stevens & Olsen, 2004) was used to select the sites for the study. This methodology is ideal for large-scale environmental sampling programs in that it is designed to characterize a system with many sampling locations and produce a sampling population that is spatially balanced. The sampling population can also be selected such that some portions of the system are more intensively sampled than others. Since previous studies have shown that UIC devices located in areas with greater than 1,000 vehicle trips per day have significantly different stormwater

characteristics than UIC devices located in areas with less than 1,000 trips per day (Kennedy/Jenks, 2009; Portland SAP, 2006b), the GRTS survey design can be manipulated to select a greater proportion of sites in areas with greater than 1,000 trips per day (Gresham, 2009).

30 sample points were located in areas with less than 1,000 trips per day and 30 sample points were located in areas with greater than 1,000 trips per day. Samples were generally taken from stormwater flowing into a catch basin inlet or sedimentation manhole. In some instances where crowned streets are present and there are two catch basins connected to a single UIC device (*FIGURE 3*), the sample only represented stormwater from one side of the street.

Figure 3. Example of a crowned street with one catch basin inlet (square) on each side of the street draining to a single UIC device (circle). Street flow is represented by the arrow.

Two sites were resampled during the study; one site (UIC-037) was sampled after oil was illegally dumped into the catch basin and so the data was considered to be atypical of usual conditions in that contributing area. A second site (UIC-045), located on SE Stark Street, was resampled to confirm high pollutant loads in the stormwater sample collected during a high intensity rainfall event. The second sample was collected during a lower intensity rainfall event and had lower concentrations of pollutants.

Figure 4. Histogram of pentachlorophenol concentrations ($\mu\text{g/L}$) in stormwater samples ($n=62$) from the 2009-2010 Gresham Wet Weather Study. Eight samples were above the SDWA maximum contaminant level of $1\mu\text{g/L}$. The method reporting limit for PCP is $0.04\mu\text{g/L}$. Non-detects are reported at this concentration.

The 62 samples were collected on seven days between December 14, 2009 to February 11, 2010. Rainfall during the collection events was classified as “heavy” for 5 samples, “moderate” for 21 samples, “light” for 31 samples, and “not raining” for 5 samples (*FIGURE 5a*). Runoff rates to the catch basin inlet were classified as “abundant” for 13 samples, “moderate” for 34 samples, and “minimal” for 35 samples (*FIGURE 5b*). The intensity of rainfall and runoff rates recorded for each sample were subjective, based on the judgment of the stormwater sample collector. PCP concentration in stormwater ranged from $0.04\mu\text{g/L}$ – $9.1\mu\text{g/L}$ (mean= $0.74 \mu\text{g/L}$, median= $0.12 \mu\text{g/L}$). As seen in *Figure 4*, 8 of the 62 samples (13%) exceeded

the PCP maximum contaminant level of 1 µg/L. 33% of the samples had a PCP concentration of 0.04 µg/L, the method reporting limit, and all of these UIC devices were located on streets with less than 1,000 vehicles trips per day (equivalent to the “residential” functional class). It is likely that some of these samples at the method reporting limit were actually below the detection limit. The 60 UIC devices selected for this study, as well as the PCP concentrations found in the stormwater samples, were used for the sites in the present study with the exception of the first sample from UIC-037 (total of n=61).

Figure 5a & 5b. Boxplot of PCP concentration in 61 stormwater samples based on **a)** rainfall intensity (heavy: n=5; moderate: n=21; light: n=31; not raining: n=5) and **b)** runoff rates (abundant: n=13; moderate: n=34; minimal: n=15) during the time the sample was collected. The method reporting limit for PCP is 0.04µg/L. Non-detects are reported at this concentration.

3) GSI Water Solutions Report (2011b)

GSI Water Solutions, Inc. was contracted by the City of Gresham to model the fate and transport of PCP; naphthalene; DEHP; 2,4-D; and toluene in groundwater and to determine whether the SDWA MCL and MADL (1 µg/L) in Portland's WPCF permit could be increased while still protecting groundwater and meeting the requirements of OAR 340-040. They used EPA's BIOSCREEN model and an existing unsaturated zone fate and transport model (Fate and Transport Tool) in their investigation (GSI, 2011b).

The Fate and Transport Tool estimated pollutant attenuation in the unsaturated zone using the Advection Dispersion Equation under average and reasonable maximum scenarios. The model showed that at an EDL of 1 µg/L, PCP would require 2.4 feet of unsaturated zone under the average scenario and 17.5 feet under the reasonable maximum scenario before it would attenuate to the method reporting limit of 0.04 µg/L. Under the reasonable maximum scenario, PCP would require 9.61 feet to attenuate below the EDL. It was noted in the memorandum that the reasonable maximum scenario represents the worst-case scenario and not reasonably likely conditions. It is used more for the purpose of evaluating model sensitivity (GSI, 2011b).

Based on the Fate and Transport Tool, GSI Water Solutions recommended that the EDL for PCP entering UIC devices be increased to 10 µg/L under the assumptions that the recommended EDLs were limited to ten times the existing EDLs and that the separation distance between the bottom of an UIC device and seasonal high water table is ten feet. GSI Water Solutions also assumed that when pollutant concentrations just above the groundwater table are below the method reporting limit, that groundwater is protected (GSI, 2011b).

The BIOSCREEN model was used to evaluate horizontal movement of a pollutant from the UIC in saturated conditions due to the fact that the reasonable maximum scenario for PCP showed that it would take greater than ten feet of vertical transport through the unsaturated zone to attenuate below the method reporting limit. The model assumed a maximum allowable horizontal travel distance of ten feet to be protective of human health (GSI, 2011b).

The model found that when 10 µg/L of PCP is discharged to a UIC device with five feet of separation from the bottom of the UIC to the top of the water table, the concentration of PCP reaching groundwater will be 4.27 µg/L. Once in the saturated zone, PCP will travel approximately two feet under average conditions and 7.5 feet under reasonable maximum conditions before concentrations are less than the method reporting limit (GSI, 2011b). ODEQ is in the process of updating the UIC WPCF Municipal Permit template to reflect some of the findings of this study.

Purpose & Need

The City of Gresham has applied for a Water Pollution Control Facility (WPCF) permit from the Oregon Department of Environmental Quality (DEQ) for the approximately 1,100 underground injection control (UIC) devices it owns and operates. Based on data collected by both Gresham and the City of Portland, which was the first municipality in the nation to receive a WPCF permit for Class V Underground Injection Control devices in 2005, pentachlorophenol (PCP) is found in stormwater at levels that exceed limits set by DEQ to protect drinking water in nearly 15% of UICs sampled. PCP in urban stormwater in the Portland metropolitan area primarily comes from the runoff from utility poles, although could also emanate from TriMet

MAX tracks (T. Lindbo, personal communication), fence posts, or other treated wood products in UIC contributing areas.

Until recently, the DEQ Municipal UIC WPCF Permit Template listed the maximum daily allowable discharge (MADL) for PCP at 1.0 µg/L. This is the current MADL for the City of Portland permit, and is also consistent with the maximum contaminant level (MDL) in the Safe Drinking Water Act. Based on new information, DEQ is revising the effluent discharge limit (EDL) of PCP in the UIC WPCF Permit Template to 10 µg/L. (See information presented in Previous Investigations: GSI Water Solutions, Inc. (2011a), above, for additional information).

In order to remain in compliance with the permit once it is issued, the City of Gresham is seeking to identify characteristics of UIC contributing areas that show increased levels of PCP in stormwater. Since the City of Gresham does not have the budget to maintain an extensive monitoring program of all 1,100 UICs, it would prefer to target specific UICs that have a higher probability to be non-compliant.

This study is an attempt to differentiate between utility pole characteristics, such as age or installation in an impervious surface, in UIC device contributing areas that may cause increased levels of PCP in stormwater runoff. Groundwater protection is a primary goal for the City of Gresham stormwater management program, as the City currently owns and operates a municipal drinking water well system that has a delineated wellhead protection area (City of Gresham, 2011a). The goal of this research is to assist the City of Gresham in identifying those UICs within the citywide system with a higher likelihood of having PCP concentrations in excess of what is protective of safe drinking water requirements for groundwater. A secondary goal, since the EDL for PCP has increased from 1.0 µg/L to 10.0 µg/L in the UIC WPCF permit

template, is to determine priority areas for mitigation efforts to ensure that all WPCF permit conditions are met.

MATERIALS & METHODS

Site Description & Gresham Hydrogeology

The City of Gresham is located in Multnomah County, Oregon and is the fourth largest city in the state. The City covers approximately twenty-six square miles and includes four watersheds: Fairview Creek, Johnson Creek, Kelley Creek, and the Columbia Slough (Gresham, 2011b) (*FIGURE 1*). Gresham has a mild climate with cool, moist winters and warm, dry summers. The annual average precipitation is 38-42" with the majority of precipitation falling between October and March of each year. The primary supply of water is purchased from the Portland Water Bureau and comes from the Bull Run watershed. During summer months, this supply is augmented by groundwater from the Cascade Wellfield, which draws water from the Sand and Gravel aquifer (Gresham Water Quality Information).

Gresham is also located in the Portland basin, a 1300 square mile area bounded by the Tualatin Mountains to the west, Lewis River to the north, Cascade foothills to the east, and Clackamas River to the south (McFarland & Morgan, 1996). The Portland basin is made up of eight major hydrogeologic units, described by Swanson, et al. in 1993 as older rocks, sand and gravel aquifer, confining unit 2, Troutdale sandstone aquifer, confining unit 1, Troutdale gravel aquifer and unconsolidated sedimentary rock aquifer. The primary aquifers in the Gresham region are in the two uppermost units (Snyder, 2008).

Figure 6a & 6b. a) USGS hydrogeologic map of the Portland basin and **b)** cross sectional view of hydrogeologic units. Yellow: unconfined sedimentary aquifer; orange: Troutdale gravel aquifer; dark brown: confining unit 1 or 2; light brown: Troutdale sandstone aquifer; green: sand and gravel aquifer; purple: older rocks.(McCarthy 1996)

The uppermost hydrogeologic unit in southeast Gresham is the Troutdale gravel aquifer (denoted by orange color in *FIGURE 6a*). This aquifer overlies confining unit 1 and underlies the unconsolidated sedimentary aquifer, as seen in *FIGURE 6b*. It is made up of poorly to moderately cemented conglomerate and sandy conglomerate. It also includes thick local accumulations of lavas and mantling soil horizon. This unit varies in thickness of 100 – 400 feet,

with a maximum thickness of 800 feet in the locations of Boring Lava or Cascade volcanics. It has a relatively high permeability, making it a productive source of groundwater for the Portland basin (Swanson et al., 1993).

The unconsolidated sedimentary aquifer is the uppermost hydrogeologic unit in northwest Gresham (denoted by yellow color in *FIGURE 6a* above). It lies above the Troutdale gravel aquifer, as seen in *FIGURE 6b*, and consists of mostly catastrophic flood deposits from the Missoula floods as well as some water bearing alluvial deposits along smaller streams in the basin. This unit has an average thickness of 50 – 100 feet, with a maximum thickness of about 250 – 300 feet under the Columbia River flood plain at Sauvie Island. It is also considered the most productive aquifer in the Portland basin due to its high permeability and hydraulic conductivity (Swanson et al., 1993).

The Cascade Wellfield, Gresham's secondary water supply, draws water from the sand and gravel aquifer (*FIGURE 15* includes the proposed wellhead protection area). This unit is the lowermost hydrogeologic unit, underlain only by the older rocks, and exists along the Columbia River channel. It is best described in the area of the Columbia South Shore wellfield, Portland's backup groundwater supply, where the altitude of the top of the layer ranges from minus 100 to minus 500 feet. The thickness of the layer can exceed 800 feet in the center of the basin, but will be less thick in upland areas where the older rocks are present. Municipal wells that draw water exclusively from the sand and gravel aquifer can yield between 2,000 to 3,000 gallons per minute (Swanson et al., 1993).

Knowing the approximate depth to groundwater is important for monitoring the current network of UIC devices as well as in siting new devices to be protective of groundwater quality.

In 2008, it was estimated that there were 11,000 publically owned and 25,000-35,000 privately owned UIC devices that contributed approximately 38% of groundwater recharge each year (Snyder, 2008). Snyder (2008) determined that the depth to groundwater is generally less than 300 feet in the Portland basin. These levels are predicted to fluctuate approximately 5.9 feet in the unconsolidated sedimentary aquifer and 6.5 feet in the Troutdale aquifer seasonally. As seen in *FIGURE 7*, the average depth to groundwater in Gresham's designated UIC device area is 50 feet, with a range of 10 to 100 feet.

Figure 7. Depth to groundwater for area of Gresham, Oregon containing UIC devices.

Delineation of UIC Contributing Areas

The contributing area to each UIC was delineated using tools in the ArcGIS Spatial Analyst “Hydrology” toolbox in ArcGIS (version 10.0) and maps were created in ArcInfo and ArcGIS (ESRI, 2011). This toolbox includes tools to map and evaluate hydrologic and landscape data by incorporating terrain attributes (ESRI, 2006). *FIGURE 8* is a flow chart of the steps used to derive hydrologic information from the elevation model and model a contributing area (or watershed).

Figure 8. Diagram of process used to create each UIC contributing area in ArcGIS. From *ArcGIS Desktop 10 Help Library: Spatial analyst toolbox, hydrology toolset, 2012*.

The City of Gresham provided the required input GIS layers, including a 3 foot (1m) digital elevation model (DEM), which describes the contours of the land surface, and the location of each catch basin inlet and UIC that was sampled in the 2009-2010 wet weather study described above. The location of each of these devices is typically mapped from the center of the device.

Using raster data analysis, the Spatial Analyst Hydrology tools systematically determine which areas of land will drain to a specific point: a catch basin connected to a UIC in the case of this study. The model will then locate any artificial depressions, or sinks, that exist in the elevation model that water would incorrectly flow to, fill those sinks to get a smooth surface, and create a flow accumulation grid with flow paths (*FIGURE 8*) (ESRI, 2012a). The model was run three times with snap distances of 5 feet, 10 feet, and 50 feet for the pour points, or outlets, of the contributing areas. A snap distance is the maximum distance the model will search around the pour point for the cell with the highest flow accumulation in order to more accurately place the pour point (ESRI, 2012a). See Appendix B for the detailed Spatial Analyst procedure used to delineate each contributing area and an example of a map created during this process.

Each of the three modeled contributing areas for a given UIC was visually inspected in ArcMap with regards to the location of nearby catch basins to determine which contributing area was the most accurate. Maps were then produced of each UIC and its contributing, or drainage, area for use in the collection of field data. The impervious surface area of each UIC contributing area was also calculated based on the results of the delineation.

Field Data Collection

The City of Gresham had previously collected stormwater samples from 60 UIC contributing areas in winter 2009-2010. 30 sites were located on streets with fewer than 1,000 trips per day and 30 sites were located on streets with greater than 1,000 trips per day. Street functional classes can further be described as residential (less than 1,000 trips per day) and

principle arterial, arterial, boulevard, collector, and community (greater than 1,000 trips per day). The PCP concentration ($\mu\text{g/L}$) for each site was taken from the water quality data collected during the 2009-2010 Wet Weather Study (Gresham, 2009).

At each of the 60 UIC and contributing area sites, characteristics of the utility poles and collection system were recorded during August – November 2011. It was assumed that the utility poles were in the same condition and of the same quality as they were during the 2009-2010 Wet Weather Study. This was assumed because it was found that no poles had had an inspection or were treated with additional treatment compound since 2008.

It was first noted if the catch basin was sumped or unsumped. A sumped basin has space in between the bottom of the catch basin and the outlet to the UIC where sediments and other pollutants can settle out of the stormwater. If a catch basin was present, an attempt was made to measure the depth of the sumped area in inches with a yardstick. Due to the depth and configuration of some of the catch basins, this measurement was not always taken. In some cases, there is a sedimentation manhole located in between the catch basin and the UIC. This device provides additional space for sediments and other pollutants to settle out of the stormwater before it enters the UIC. The presence or absence of a sedimentation manhole was noted for each contributing area.

A number of details were recorded for each utility pole located in a given contributing area. The pole was first given a unique identification number based on the GRTS rank of the UIC, for example the first utility pole in the contributing area for UIC-012 was assigned the unique ID of UIC-012-PP1. A GPS coordinate was recorded for each pole using a Garmin Etrex 12 Channel handheld GPS unit. The point was recorded by standing directly in front of the

utility pole in a perpendicular line to the street. The distance from the utility pole to the catch basin was recorded in feet to the nearest three feet using a 100-foot tape measure. This distance was defined as the distance from the edge of the curb to the closest edge of the catch basin, following gutter flow. If a curb was not present, it was the distance from the edge of the impervious surface to the closest edge of the catch basin following the stormwater flow path.

The circumference of the pole was measured in inches using a 100-foot tape measure. The height of the pole was categorized by one of three estimates provided by Portland General Electric (J. Donovan, personal communication):

- Wooden utility poles used only for street lights = 30-35 feet (33')
- Distribution wooden utility poles with one cross arm = 40-50 feet (45')
- Subtransmission and transmission wooden utility poles with three conductors at the top in a triangular shape and lower arms for distribution = 55-60 feet (58').

The surface area of the pole was calculated by first obtaining the radius of the pole from the measured circumference using the equation:

$$\text{Radius (ft)} = 2\pi / \text{Circumference (ft)}$$

and then using the average height of the utility pole based on the above classification to calculate surface area with the equation:

$$\text{Surface area (ft}^2\text{)} = 2\pi * \text{Radius} * \text{Height}.$$

The distance in inches from the utility pole to the curb (if present) was measured to the nearest inch using either a yardstick or 100-foot tape measure. This was defined as the perpendicular distance from the front of the pole to the edge of the curb. The substrate surrounding each pole was also recorded as being concrete, asphalt, vegetation, soil, or other.

The “other” category was used if there were two or more substrates surrounding the utility pole. If the utility pole was installed in a pervious substrate (vegetation or soil), the distance in inches to the nearest impervious surface was recorded. This distance was defined as shortest distance to an impervious surface on the perpendicular line from the utility pole to the street. It was noted if any pole treatment compound staining was visible on the ground surrounding the utility pole (*FIGURE 9*) and if so, the extent of staining as a measure of the staining radius in inches from the utility pole. Since the staining radius around the pole was generally not uniform, the maximum radius was recorded.

Figure 9. Ground staining from utility pole treatment compound.

A visual inspection of the amount of treatment compound on the utility pole was conducted by classifying the pole as having low, medium, or high amounts of treatment (*FIGURES 10a-c*).

Figure 10a-10c. Example of a utility pole with **a)** high; **b)** medium; and **c)** low treatment compound on lower portion of pole based on a visual estimation during data collection in August-November 2011. See Appendix III for a complete description of these categories.

The age of the utility pole was also visually estimated as juvenile, mature, or weathered (*FIGURES 11a-c*).

Figure 11a-11c. Example of a utility pole characterized as **a)** weathered; **b)** mature; and **c)** juvenile based on a visual estimation during data collection in August-November 2011. See Appendix III for a complete description of these categories.

Appendix C contains the instructions for the field data sheet with complete descriptions of treatment compound on pole and pole age visual estimation categories. The presence, type, and number of diffusion plugs in each pole (*FIGURES 12a&b*) was recorded as a proxy for the amount of additional treatment compound added to the utility pole during inspections by the utility company.

Figure 12a & 12b. Example of a utility pole with **a)** plastic diffusion plug and **b)** wood diffusion plug observed during data collection in August-November 2011.

If present, the Portland General Electric (PGE) power pole map number and power pole number were recorded. The pole manufacturer and manufacture year were also recorded when the tag was present. Additionally, any tags located on the poles denoting inspection years and inspection contractors were recorded.

Finally, the surrounding land use was recorded as residential, commercial, mixed residential and commercial, or industrial. The underlying soil type and soil profile to 80 inches was documented from the United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) online soil survey. Appendix C also contains the field data sheet used to collect all of the above information.

Data Analysis

A large number of variables were collected from each delineated UIC contributing area, but it was unclear which, if any of these variables would describe levels of PCP found in stormwater samples. A regression tree was the first statistical method used to explore the data. When multiple potential predictor variables are present in a data set, this model can be used to predict the strength of each variable as well as which variables have the most significant effect on the response variable. The model uses a regression tree algorithm to determine how to split the data at each node, when to stop splitting, and how to determine the value of the response variable for each predictor (Loh, 2008). Splitting is based on an impurity index for each node, where a node that predicts all replicates in one class has an impurity index equal to zero. The impurity index increases as predictive ability decreases. Additionally, the R^2 value can also be calculated at each split by the equation $1 - \text{relative error}$ (Gotelli & Ellison, 2004).

The Recursive PARTitioning (“rpart”) package (Therneau & Atkinson, 2011a) in the statistical software ‘R’ (R Development Core Team, 2011) was used to create two regression trees: one for categorical and numerical data from each individual utility pole and one using data compiled for each UIC contributing area. *TABLE 1* includes the variables used in each regression tree. This model uses a complexity parameter (cp value) to evaluate the deviance within the tree. The cp value is a proxy for the number of splits in a particular regression tree and will decrease with increasing numbers of splits. The model stops splitting the tree when the cp value gets too low and the cost of creating more groups is greater than the lack of fit of the model (Maindonald & Braun, 2006). Additionally, a summary output is available which gives detailed listings of the model, including other primary splits and surrogate splits. Other

primary splits are those that have a greater impurity index and improve the model less than the actual predictor chosen. Surrogate splits are variables with nearly the same results of the primary split, but account for the possibility of missing variables (Therneau & Atkinson, 2011b).

Table 1. Variables used in the construction of two regression trees in 'R'.

Regression Tree Based on Individual Pole Characteristics	Regression Tree Based on Contributing Area Characteristics
Surface area of utility pole	Presence of utility poles
Utility pole manufacturer	Catch basin type
Utility pole manufacture year	Street functional class
Year of last inspection	Vehicle trips per day
Distance to catch basin inlet	Rainfall intensity during sample collection
Distance to the curb	Number of utility poles
Substrate utility pole installed in	Total surface area of all utility poles
Distance to nearest impervious surface	UIC contributing area
Visual estimation of treatment product on utility pole	Ratio of utility pole surface area to UIC contributing area
Presence of product staining on ground	Number of utility poles set in concrete
Radius of product staining on ground	Surface area of all utility poles set in concrete
Visual estimation of pole age	Total distance from all poles to catch basin inlet
Presence of diffusion plugs	Average distance from all poles to catch basin inlet
Number of diffusion plugs	Maximum distance from utility pole to catch basin inlet
	Minimum distance from utility pole to catch basin inlet
	Average distance from utility poles to curb
	Soil complex

Based on the results of the regression trees, categorical data containing two groups was further compared with a Wilcoxon-Mann-Whitney rank sum test using the `wilcox.test` command from the stats package in 'R' to determine if a significant difference ($\alpha = 0.05$) existed between the groups. For categorical data containing three or more groups, the Kruskal-Wallis rank sum test was used to determine if a significant difference ($\alpha = 0.05$) existed between the groups. This test was completed in 'R' with the `kruskal.test` command from the stats package (R Core Development Team, 2011). If the p-value was less than 0.05, a Wilcoxon-Mann-Whitney rank sum test was performed for each pair of groups within the category. To account for

potential Type I errors, a Bonferri correction (α/c where c = number of tests run) was applied to the confidence level.

Scatter plots of the continuous response variables identified as important in the regression tree and PCP concentrations were constructed. Then Spearman's rank correlation (ρ) was calculated to determine if PCP concentrations in a contributing area were significantly associated with any of the response variables ($\alpha = 0.05$). Spearman's ρ was calculated in R using the `cor.test` function (R Core Development Team, 2011). The distribution of the data prohibited the use of parametric statistical analysis. Although these non-parametric statistical tests do not have the same power as parametric tests, they can still provide statistically significant trends.

Spatial Analysis

All spatial statistics were calculated in ArcGIS (version 10.0) and maps were created in ArcInfo and ArcGIS (ESRI, 2011a). Global Moran's I, a measurement of the overall trend of spatial autocorrelation (Anselin, 1995), was calculated in ArcGIS using the Spatial Autocorrelation tool in the Spatial Statistics toolbox. A high positive z-score ($\alpha = 0.05$) indicates that PCP concentrations are generally clustered while a high negative z-score indicates that PCP concentrations are generally dispersed. The Cluster and Outlier Analysis (Anselin Local Moran's I) tool was used to map the statistically significant positive and negative spatial autocorrelation on a local scale. Anselin Local Moran's I analyzed the presence of clusters and outliers of concentrations of PCP in stormwater for each of the 60 sites, based on the values of neighboring features. A high positive z-score ($\alpha = 0.05$) indicates that a particular location has a

similar high or low PCP concentration as neighboring sites. A high negative z-score ($\alpha = 0.05$) indicates a spatial outlier (Anselin, 1995), for example a site with high PCP concentration in stormwater surrounded by sites with low PCP concentration in stormwater. For each tool, spatial autocorrelation was calculated using an inverse distance of 5000 feet based on Euclidean distance.

The High/Low Clustering (Getis-Ord General G) tool in the Spatial Statistics toolbox was used to determine if there were high or low clusters of PCP concentration in stormwater in the study area. A high positive z-score ($\alpha = 0.05$) indicates clusters of high values of PCP and a high negative z-score indicates clusters of low values of PCP. The Hot Spot Analysis (Getis-Ord G_i^*) tool was used to map the statistically significant hot and cold spots on a local scale. A high positive z-score ($\alpha = 0.05$) indicates that a particular UIC site is surrounded by other sites with high PCP concentrations (a “hot spot”). A high negative z-score ($\alpha = 0.05$) indicates that a particular UIC site is surrounded by other sites with low PCP concentrations (a “cold spot”) (Getis & Ord, 1992). For each tool, neighbors were calculated using an inverse distance of 5000 feet based on Euclidean distance.

RESULTS

60 UIC contributing areas were surveyed for the presence and various characteristics of utility poles, with a total of 86 utility poles identified in 40 UIC contributing areas. *TABLE 2* contains summary information from each site. All water quality data and associated rainfall conditions for the 60 UIC sites in the present study were collected during the 2009-2010 Gresham Wet Weather study (Gresham, 2009), as described above in the “Previous

Investigations” section. All data related to utility poles was collected during August – November 2011. It is assumed that the conditions and quality of the utility poles are the same as they were during the 2009-2010 study.

Table 2. Summary data for the 60 UIC contributing areas used in this study. The System ID is the City of Gresham unique ID for each UIC device. The GRTS Rank is the ID assigned to the UIC device during the selection of spatially balanced sample points using the GRTS survey design. The Street Functional Classes arterial, boulevard, and collector have traffic volumes >1000 trips per day. The Street Functional Class residential has traffic volumes <1000 trips per day. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. See Appendix III for complete utility pole data.

System ID	GRTS Rank	Address	PCP Conc. (ug/L)	Street Functional Class	Rainfall Intensity	# of Poles	Total Pole Surface Area (ft ²)	Surface Area of Poles in Concrete (ft ²)	Min. Distance from Pole to Inlet (ft)	Avg. Distance from Pole to Curb (ft)
3349-J-088	UIC-001	35 NW PHYLLIS CT	0.04	Residential	Moderate	1	43.23	0	495	1.17
3152-F-032	UIC-002	21333 SE ALDER ST	0.04	Residential	Moderate	2	281.25	0	54	2.08
3047-W-004	UIC-003	16714 NE Glisan St.	0.348	Arterial	Not Raining	3	536.5	536.5	10	1.3
3348-W-029	UIC-004	2826 SE 176th Pl.	0.0962	Residential	Moderate	0	0	0	NA	NA
3047-W-032	UIC-007	307 SE 167th Ave.	0.0451	Residential	Moderate	0	0	0	NA	NA
3249-W-045	UIC-008	1634 SE 182nd Ave.	0.0926	Residential	Light	0	0	0	NA	NA
3050-W-067	UIC-009	322 NE 193RD AVE	0.04	Residential	Moderate	0	0	0	NA	NA
3153-F-051	UIC-010	2863 NE Elliott Ave.	0.0939	Residential	Moderate	2	145.18	0	81	1.42
3048-W-098	UIC-011	17727 E BURNSIDE	0.827	Collector	Moderate	3	472.5	0	24	11.86
3249-W-048	UIC-012	2446 SE 190th Ave.	1.06	Collector	Light	2	354.01	256.36	15	1.13
3050-W-028	UIC-013	41 NE 194th Ave.	0.04	Residential	Light	0	0	0	NA	NA
3153-F-041	UIC-014	1253 NW EASTMAN PKWY	0.162	Arterial	Moderate	1	142.65	0	66	7.25
3149-W-079	UIC-015	19010 E BURNSIDE	0.884	Collector	Moderate	5	742.95	555.3	18	1.1
3449-J-006	UIC-017	310 SW Hartley Ave.	0.04	Residential	Moderate	1	82.5	0	75	0.83
3151-F-054	UIC-018	20909 SE Main Dr.	0.04	Residential	Heavy	0	0	0	NA	NA
2947-W-059	UIC-019	16585 NE Oregon St.	0.04	Residential	Light	3	214.83	71.61	60	1.08
3348-W-015	UIC-020	3223 SE 176th Pl.	0.04	Residential	Moderate	0	0	0	NA	NA
3055-B-027	UIC-021	3417-3419 NE VIEW AVE	0.504	Arterial	Heavy	3	502.2	172.35	36	4.89
3153-F-021	UIC-022	22200 SE STARK ST.	0.147	Arterial	Not Raining	2	341.1	0	6	8.63
3047-W-109	UIC-023	17044 SE BURNSIDE ST	0.197	Collector	Light	1	227.36	227.36	111	2.92
3249-W-026	UIC-024	18443 SE Lincoln St.	0.0597	Residential	Light	1	68.64	0	30	1.5
3050-W-050	UIC-025	19716 NE Flanders St.	0.04	Residential	Light	0	0	0	NA	NA
3349-W-056	UIC-028	18630 SE DIVISION ST	0.123	Arterial	Light	2	226.35	0	66	9.75
3150-F-010	UIC-029	2515 NW Eleven Mile Ave.	0.133	Residential	Light	3	484.2	0	36	4.09
3152-F-082	UIC-030	439 NW 24th St.	0.04	Residential	Moderate	0	0	0	NA	NA
3149-W-042	UIC-031	18655 SE Yamhill Cir.	0.102	Residential	Light	1	131.4	0	15	1.08
2947-W-008	UIC-032	16516 NE Holladay St.	0.04	Residential	Light	0	0	0	NA	NA

System ID	GRTS Rank	Address	PCP Conc. (ug/L)	Street Functional Class	Rainfall Intensity	# of Poles	Total Pole Surface Area (ft2)	Surface Area of Poles in Concrete (ft2)	Min. Distance from Pole to Inlet (ft)	Avg. Distance from Pole to Curb (ft)
3152-F-050	UIC-034	1047 SE 213th Ave.	0.04	Residential	Moderate	0	0	0	NA	NA
2949-W-042	UIC-035	805 NE 190th Ave.	0.04	Residential	Light	3	351.06	0	102	1.25
3149-W-015	UIC-036	1209 SE 190th Ave.	0.172	Collector	Light	1	96.36	0	27	16
3155-K-041	UIC-037	2150 NE Country Club Ct.	0.04	Residential	Light	0	0	0	NA	NA
3052-F-020	UIC-038	21414 SE ANKENY ST	0.04	Residential	Moderate	0	0	0	NA	NA
3048-W-014	UIC-039	17347 SE STARK ST	0.223	Arterial	Light	1	174	174	150	5.92
3348-W-011	UIC-040	3307 SE 180th Ave.	0.04	Residential	Moderate	0	0	0	NA	NA
3149-W-019	UIC-041	19110 SE STARK ST	2.6	Boulevard	Moderate	1	251.14	251.14	96	4.83
3152-F-058	UIC-042	21430SE Salmon St.	0.04	Residential	Light	0	0	0	NA	NA
3049-W-039	UIC-043	241 SE 188th Ave.	0.1	Residential	Light	0	0	0	NA	NA
3050-W-019	UIC-045A	425 SE 196TH AVE	6.89	Boulevard	Heavy	2	282.6	282.6	12	3.38
3050-W-019	UIC-045B	425 SE 196TH AVE	0.659	Boulevard	Light	2	282.6	282.6	12	3.38
3048-W-021	UIC-046	17440 NE Flanders St.	0.04	Residential	Not Raining	0	0	0	NA	NA
3149-W-059	UIC-047	636 SE 182nd Ave.	0.354	Residential	Not Raining	4	630.54	0	27	5
2946-W-002	UIC-048	16145 NE GLISAN ST	0.947	Arterial	Light	5	1282.86	763.86	2	1.55
3449-J-073	UIC-049	4020 SE 182nd Ave.	0.17	Residential	Light	2	240	157.5	30	1.04
3250-F-007	UIC-050	1919 NW Eleven Mile Ave.	0.9	Residential	Moderate	1	135	135	78	22
3047-W-027	UIC-051	276 SE 172nd AVE	5.74	Collector	Light	2	388.35	388.35	12	0.92
3149-W-003	UIC-052	1274-1288 SE 182ND AVE	1.79	Arterial	Light	2	386.14	386.14	15	1.09
2950-W-063	UIC-053	19827 NE Holladay St.	0.04	Residential	Not Raining	1	76.89	0	105	1.25
3053-F-020	UIC-054	22309 SE STARK ST	0.08	Arterial	Moderate	0	0	0	NA	NA
3048-W-097	UIC-055	17730 E BURNSIDE ST	0.216	Collector	Light	2	449.5	0	72	11.04
3050-W-016	UIC-057	19415 SE STARK ST	9.1	Boulevard	Heavy	3	612.22	612.22	24	1.64
3049-W-069	UIC-059	18702 E BURNSIDE ST	0.0862	Boulevard	Moderate	0	0	0	NA	NA
3047-W-096	UIC-060	16300 SE BURNSIDE ST	0.518	Collector	Light	4	768.5	526.64	36	2.73
3150-F-043	UIC-061	835 SE 202ND AVE	0.118	Collector	Heavy	1	241.86	241.86	252	1.83
3047-W-047	UIC-062	211 NE 172nd Ave.	0.163	Collector	Light	1	112.5	0	90	13
3153-F-025	UIC-070	815 SE 223RD AVE	0.149	Arterial	Light	1	99	0	225	13.5
3047-W-103	UIC-071	16801 E BURNSIDE	0.139	Collector	Light	1	142.65	0	66	10.83
3153-F-017	UIC-086	22300 SE STARK ST	5.96	Arterial	Moderate	3	605	605	1	3.64
3150-F-047	UIC-093	20132 SE STARK ST	2.04	Arterial	Light	2	319.05	319.05	42	1.04
3254-F-072	UIC-094	1685 NE Cleveland St.	0.449	Collector	Light	5	406.56	406.56	3	1.93
3248-W-020	UIC-100	1925 SE 182ND AVE	0.0926	Arterial	Light	0	0	0	NA	NA
3048-W-091	UIC-103	17376 NE COUCH ST	0.204	Collector	Moderate	2	262.35	127.35	99	5.46

Summary Data

Of the 60 sites, 20 (33%) do not contain any utility poles (*FIGURE 14*, sites with no black diamonds). PCP concentrations ranged from $<0.04\mu\text{g/L}$ – $0.1\mu\text{g/L}$, with 70% of these sites having a PCP concentration below the method reporting limit of $0.04\mu\text{g/L}$ (*FIGURE 13*). Many sites are located on streets that either have underground utilities or utility poles installed in alleys in between houses. In some cases, utility poles are located on the opposite side of the street from where the sample was collected (See *FIGURE 3*). 85% of sites without utility poles are located on streets with less than 1,000 vehicle trips per day (equivalent to the “residential” functional class) where, often times, metal light poles have replaced older wood poles. The remaining 15% of sites without utility poles are located on arterials and boulevards.

The Mann-Whitney U test ($\alpha=0.05$) found that PCP concentration in stormwater is significantly different in UIC device contributing areas with and without utility poles present ($p\text{-value}=<0.001$). See *FIGURE 13 boxplots* for boxplots of PCP concentration in contributing areas with and without utility poles present.

Figure 13. Boxplots of pentachlorophenol concentration ($\mu\text{g/L}$) for all contributing areas ($n=60$), contributing areas with utility poles present ($n=40$), and contributing areas with no utility poles present ($n=20$). Significant differences ($\alpha=0.05$) in PCP concentration were found between sites with utility poles present and sites without utility poles present. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is $0.04\mu\text{g/L}$. Non-detects are reported at this concentration.

UIC Sample Points & Utility Poles in Contributing Drainage Area

Figure 14. The location of UIC devices included in the 2009-2010 wet weather study and the associated utility poles located in each contributing area. Red points indicate a pentachlorophenol concentration greater than 1µg/L. Wellfield protection areas are located in the northern area of the city. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011.

Eight UIC contributing areas had a PCP concentration greater than $1\mu\text{g/L}$, exceeding the current SDWA maximum concentration limit (MCL), with a range of $1.06\mu\text{g/L} - 9.1\mu\text{g/L}$ (red points in *FIGURE 15*). *TABLE 3* contains the data from each utility pole located in one of the eight contributing areas with PCP concentrations greater than $1\mu\text{g/L}$. All of these sites are located on streets with greater than 1,000 vehicle trips per day and five of the sites are located on SE Stark Street. Each site has a utility pole less than 100 feet from the catch basin inlet. Seven of the eight sites have a utility pole less than 50 feet from the catch basin inlet and six of the eight sites have a utility pole less than 25 feet from the catch basin inlet.

With the exception of a utility pole in the contributing area at SE 190th and SE Division (PCP concentration = $1.06\mu\text{g/L}$), every utility pole is set in concrete. Each site, with the exception of the site at SE 190th and SE Division, has at least one utility pole with treatment compound staining on the concrete surrounding the pole. Seven of the eight sites (exception at SE Stark & 202nd) have had utility pole inspections in the last 10 years and have plastic diffusion plugs in at least one utility pole, if not all. The contributing area at SE Stark & SE 194th (PCP concentration = $9.1\mu\text{g/L}$) has two utility poles located less than 75 feet from the catch basin inlet and all utility poles are less than two feet from the curb. It also has the largest cumulative utility pole surface area of the eight sites.

Table 3. Characteristics of utility poles located in contributing areas with greater than 1µg/L PCP in stormwater. For adjacent land use, COM = Commercial and RES = Residential. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011.

System ID	3249-W-048		3149-W-019	3050-W-019		3047-W-027		3149-W-003	
Power Pole Unique ID	UIC-012-PP1	UIC-012-PP2	UIC-041-PP1	UIC-045-PP1	UIC-045-PP2	UIC-051-PP1	UIC-051-PP2	UIC-052-PP1	UIC-052-PP2
Penta Conc. (ug/L)	1.06	1.06	2.6	6.89	6.89	5.74	5.74	1.79	1.79
Cross Streets	SE 190TH & DIVISION	SE 190TH & DIVISION	SE STARK & BURNSIDE	SE STARK & 196TH	SE STARK & 196 TH	SE 172ND & PINE	SE 172ND & PINE	SE 182ND & MAIN	SE 182ND & MAIN
Catch Basin Type	SUMPED	SUMPED	SUMPED	SUMPED	SUMPED	SUMPED	SUMPED	SUMPED	SUMPED
Sed Manhole	YES	YES	NO	NO	NO	NO	NO	NO	NO
Functional Class	COLLECTOR	COLLECTOR	BOULEVARD	BOULEVARD	BOULEVARD	COLLECTOR	COLLECTOR	ARTERIAL	ARTERIAL
Surface Area (ft ²)	256.36	97.65	251.14	183.6	99	127.35	261	251.14	135
Pole Manufacturer	TAYLOR TREATING	PENTAFIR	PENTAFIR	TAYLOR TREATING		PENTAFIR	DFP	PENTAFIR	PENTAFIR
Manufacture Year	1999	1984	1982	1995	1955	1968		1976	1968
Last Inspection	2008	2007	2002	2002	1993	2008	2008	2008	1989
Distance UIC Inlet (ft)	15	135	96	12	120	171	12	150	15
Distance Curb (ft)	0.83	1.42	4.83	1.42	5.33	0.92	0.92	1.17	1
Surface Surrounding Pole	CONCRETE	VEGETATION	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
Treatment Product Visible Pole	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	HIGH
Treatment Compound Ground	NO	NO	YES	YES	NO	NO	YES	YES	YES
Pole Appearance	JUVENILE	MATURE	MATURE	MATURE	WEATHERED	WEATHERED	MATURE	MATURE	MATURE
Diffusion Plugs Present	PLASTIC	PLASTIC	PLASTIC	PLASTIC	WOOD	PLASTIC	PLASTIC	PLASTIC	WOOD
Number Diffusion Plugs	4	4	7	5	2	5	4	8	4
Adjacent Land Use	RES	RES	COM	COM	COM	RES	RES	RES	COM/RES
Soil Complex Name	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Silt Loam	Multnomah Silt Loam

System ID	3050-W-016			3153-F-017			3150-F-047	
Utility Pole Unique ID	UIC-057-PP1	UIC-057-PP2	UIC-057-PP3	UIC-086-PP1	UIC-086-PP2	UIC-086-PP3	UIC-093-PP1	UIC-093-PP2
Penta Conc. (ug/L)	9.1	9.1	9.1	5.96	5.96	5.96	2.04	2.04
Cross Streets	SE STARK & 194TH	SE STARK & 194TH	SE STARK & 194TH	SE STARK & 223RD	SE STARK & 223RD	SE STARK & 223RD	SE STARK & 202ND	SE STARK & 202ND
Catch Basin Type	SUMPED	SUMPED	SUMPED	UNSUMPED	UNSUMPED	UNSUMPED	SUMPED	SUMPED
Sed Manhole	NO	NO	NO	NO	NO	NO	NO	NO
Functional Class	BOULEVARD	BOULEVARD	BOULEVARD	ARTERIAL	ARTERIAL	ARTERIAL	ARTERIAL	ARTERIAL
Surface Area (ft ²)	212.86	157.5	241.86	290	172.35	142.65	153.9	165.15
Pole Manufacturer	PENTAFIR	MCFARLANE CASCADE	PENTAFIR	TAYLOR TREATING	TAYLOR TREATING	PENTAFIR	TAYLOR TREATING	PENTAFIR
Manufacture Year	1989	2008	1989	1996	1996	1968	1994	1965
Last Inspection	2002		2002	2007	2007	2007		1989
Distance UIC Inlet (ft)	126	24	69	156	1	123	42	216
Distance Curb (ft)	1.33	1.67	1.92	5.17	4.67	1.08	1.08	1
Surface Surrounding Pole	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
Treatment Product Visible Pole	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	LOW
Treatment Compound Ground	YES	YES	YES	YES	YES	YES	YES	NO
Pole Appearance	MATURE	JUVENILE	MATURE	MATURE	MATURE	MATURE	MATURE	WEATHERED
Diffusion Plugs Present	PLASTIC	NO	PLASTIC	PLASTIC	PLASTIC	PLASTIC	NO	WOOD
Number Diffusion Plugs	6		8	8	8	4		4
Adjacent Land Use	COM	COM	COM	COM	COM	COM	COM	COM
Soil Complex Name	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex	Latourell Urban Land Complex	Latourell Urban Land Complex	Latourell Urban Land Complex	Multnomah Urban Land Complex	Multnomah Urban Land Complex

Data Analysis – Utility Poles Characteristics

Regression Tree Analysis

The exploratory regression tree analysis of the characteristics of each utility pole (see list of characteristics assessed for each location in *TABLE 1*) concluded that the substrate

surrounding the utility pole is the best predictor of PCP concentration in stormwater
($cp=0.2096$, $R^2=.21$) (FIGURE 15).

Figure 15. Output from regression tree analysis comparing pentachlorophenol concentration (response variable) to categorical and continuous data (predictor variables) for each individual utility pole. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The tree was created in ‘R’ using the “rpart” functions.

Utility poles installed in concrete (sidewalks) split to the right, while all other substrates (asphalt, dirt, other, and vegetation) split to the left. 41 of the 86 utility poles identified in the study are set in concrete. Other primary splits with lower improvement of the impurity index for the first node were the pole manufacture year, presence of utility pole treatment compound staining on the ground, and the pole manufacturer (*TABLE 4*). The presence of utility pole treatment compound staining on the ground was also a surrogate split for the first node (68.6% agreement).

Table 4. Summary output for node number one of utility pole characteristic regression tree from 'R'.

Primary Splits for Node #1	Improvement in Impurity Index
Substrate Surrounding the Utility Pole	0.2097
Utility Pole Manufacture Year	0.1114
Presence of Utility Pole Treatment Compound Staining on Ground	0.0983
Utility Pole Manufacturer	0.0922

The boxplots for each of these utility pole characteristics (*FIGURES 16-19*) seem to confirm the results of the regression tree analysis. There is a higher concentration of PCP in stormwater when a utility pole is surrounded by concrete, ground staining from utility pole treatment compound is present on the substrate surrounding the pole, or when the utility pole is younger in age.

Figure 16. Boxplot of PCP concentrations versus substrate the utility pole is installed in: asphalt (n=1); concrete (n=41); soil (n=28); vegetation (n=15); other (n=1). Significant differences ($\alpha=0.05$) in PCP concentration were found between sites with utility poles surrounded by concrete (a) and sites with utility poles surrounded by other substrates (b). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is $0.04\mu\text{g/L}$. Non-detects are reported at this concentration.

Figure 17. Boxplot of pentachlorophenol concentration in stormwater based on the age of the utility pole. The groups in the “Year” category are as follows, based on the results of the regression tree nodes: “Old”=manufactured prior to 1970 (n=23); “Middle”=manufactured between 1970 and 1988 (n=27); “Young”=manufactured after 1988 (n=24); “Unknown”=no identification tag present on pole (n=12). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is 0.04µg/L. Non-detects are reported at this concentration.

Figure 18. Boxplot of pentachlorophenol concentration in stormwater based on the presence (n=38) or absence (n=48) of treatment compound staining on the ground surrounding the utility pole. Significant differences ($\alpha=0.05$) in PCP concentration were found between sites with ground staining present (b) and sites without ground staining present (a). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is 0.04µg/L. Non-detects are reported at this concentration.

Figure 19. Boxplot of pentachlorophenol concentration in stormwater versus the utility pole manufacturer. Manufacturers are listed from left to right in order of when they were in production: Pentaflir (n=48) 1962-1990; Taylor Treating (n=10) 1994-1999; DFP (n=4) 1998; McFarlane Cascade (n=2) 2009; Other (n=3); Unknown (n=18). Utility poles listed as “Other” are from manufacturers with only one utility pole identified in the study area with production years of 1960, 2002, and 2010. Utility poles listed as “Unknown” are those poles where the identification tag was either removed or had fallen off. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is 0.04µg/L. Non-detects are reported at this concentration.

The second node of the regression tree was split based on the year the utility pole was manufactured; specifically it differentiates between poles manufactured before and after 1988 (cp=0.1463, $R^2=0.15$). This is supported by *FIGURE 19*, which shows that utility poles manufactured by Taylor Treating, DFP, and McFarlane Cascade result in higher concentrations

of PCP in stormwater than utility poles manufactured by Pentaflir. The third node differentiates between poles located greater than and less than 1.125 feet from the curb ($cp=0.0461$, $R^2=0.04$). Other primary splits in the third node with lower improvement of the impurity index were the distance from the utility pole to the catch basin inlet, the number of diffusion plugs in the utility pole, and the year of the last inspection of the pole (*FIGURE 15*).

Non-parametric Data Analysis

66% of UIC sites examined in this study had utility poles in the contributing area, and nearly half of those utility poles were set in concrete (41 out of 86). PCP concentration in the stormwater samples from sites with utility poles set in concrete ranged from $<0.04\mu\text{g/L}$ – $9.1\mu\text{g/L}$. Based on the boxplot in *FIGURE 16*, it appears that when utility poles are surrounded by concrete the result is higher concentrations of PCP in the contributing area stormwater. A Mann-Whitney U-test found significant differences ($\alpha=0.05$, $p\text{-value}= <0.001$) in PCP concentration when are utility poles surrounded by concrete (median= $0.88\mu\text{g/L}$, mean= $2.31\mu\text{g/L}$) and when utility poles surrounded by asphalt, soil, or vegetation (median= $0.15\mu\text{g/L}$, mean= $0.29\mu\text{g/L}$). The majority of sites without utility poles set in concrete are located on residential streets, with the remaining located on community or arterial streets.

The Mann-Whitney U-test also found significant differences ($\alpha=0.05$) in PCP concentration when there are utility poles with ground staining (median= $0.70\mu\text{g/L}$, mean= $2.03\mu\text{g/L}$) and when there is no ground staining (median= $0.28\mu\text{g/L}$, mean= $0.64\mu\text{g/L}$) around utility poles ($p=0.002$) (*FIGURE 18*).

It appears that there is a correlation between the age of the pole and the concentration of PCP in the contributing area. *FIGURES 17 & 20* show a slight trend that as utility pole age decreases, PCP concentration in the contributing area increases. Some older utility poles with diffusion plugs present had higher concentrations of PCP in the contributing area, especially if the diffusion plugs were plastic and not wood.

Diffusion plugs are inserted into the pole after additional treatment product has been added during an inspection. Inspection of utility poles usually occur every ten years, so many of the youngest utility poles did not have diffusion plugs. Based on inspection tags, wood diffusion plugs were used until the mid-1990s and plastic diffusion plugs were used exclusively after 2000. *FIGURE 21* also shows that while some older poles with wood diffusion plugs are located in a UIC contributing area with a high concentration of PCP, there is also a younger pole with no diffusion plugs or plastic diffusion plugs located in the same contributing area.

Figure 20. Pentachlorophenol concentration ($\mu\text{g/L}$) in a UIC device contributing area as a response to the year a given utility pole in the contributing area was manufactured. Data is based off of 74 utility poles. 12 of the 86 utility poles identified did not have an identification tag with the year manufactured. Symbols represent the presence and type of diffusion plug found at each utility pole. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011.

Further, the Mann-Whitney U-test found significant differences ($\alpha=0.05$) in PCP concentrations between utility poles that were inspected after the year 2000 and before the year 2000 (median_{after 2000} PCP=0.52 $\mu\text{g/L}$, mean_{after 2000} PCP=1.77 $\mu\text{g/L}$; median_{before 2000} PCP=0.13 $\mu\text{g/L}$, mean_{before 2000} PCP=0.58 $\mu\text{g/L}$; p-value=<0.001). For this test, utility poles were considered to have had an inspection after the year 2000 if an inspection tag was present indicating so, if plastic diffusion plugs were present, or if the pole was installed after 2000. Utility poles were considered not to have had an inspection after the year 2000 if an inspection

tag indicated an earlier inspection year, wood diffusion plugs were present, or the pole was installed prior to 2000 and had no diffusion plugs.

The Kruskal-Wallis test confirmed significant differences ($\alpha=0.05$) in PCP concentrations based on the visual estimation of the amount of treatment product on the utility pole (median_{high} PCP=0.40 $\mu\text{g/L}$; median_{medium} PCP=0.50 $\mu\text{g/L}$; median_{low} PCP=0.15 $\mu\text{g/L}$; p-value=0.013, *FIGURE 21*). Based on the regression tree analysis, this characteristic is less important in determining PCP concentration in stormwater than those utility pole characteristics discussed above.

Figure 21. Boxplot of pentachlorophenol concentration in stormwater based on a visual estimation of treatment compound staining on the lower 6 feet of the utility pole. Low: n=21; Medium: n=35; High: n=30. Significant differences ($\alpha=0.05$) in PCP concentration were found between utility poles with a low estimation of treatment compound staining (b) utility and utility poles with a medium or high estimation of treatment compound staining (a). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is 0.04 $\mu\text{g/L}$. Non-detects are reported at this concentration.

A pairwise comparison with the Mann-Whitney U test ($\alpha=0.016$ after Bonferri correction) found that PCP concentration from contributing areas containing utility poles with a low amount of treatment product visible on the pole were significantly different from both contributing areas containing utility poles with medium and high amounts of treatment product visible on the pole. There were no differences in PCP concentration from contributing areas with high or medium amounts of treatment product visible on the pole. *TABLE 5* is a summary of the Mann Whitney U test results.

Table 5. Summary of results from Mann-Whitney U test ($\alpha=0.016$) to compare the concentration of pentachlorophenol in stormwater to the three different categories of the visual estimation of treatment compound on a utility pole. A Bonferri correction was used to account for an increase in Type I error with multiple comparisons.

Visual Estimation of Treatment Product on Utility Pole	W	p-value
High vs. Medium	514.5	0.6137
High vs. Low	446.5	0.012
Medium vs. Low	222.5	0.007228

Data Analysis – Contributing Area Characteristics

Regression Tree Analysis

The regression tree used to explore the characteristics of each UIC device contributing area found that the most important criteria affecting the concentration of PCP is the total surface area of utility poles set in concrete in a particular contributing area ($cp=0.4079$, $R^2=0.41$). The split occurs when the surface area of utility poles set in concrete is greater or less than 246.5 square feet. 14 of 60 sites in the study have a total surface area of utility poles set in concrete greater than 246.5 square feet (14 of 40 sites with utility poles present). Other primary splits with a lower improvement of the impurity index were the number of poles set in concrete, the minimum distance to the catch basin inlet, the total surface of all utility poles,

and the ratio of utility pole surface area to UIC contributing area (*TABLE 6*). Scatterplots for these data sets are presented in *FIGURES 22-24* below in the discussion of Spearman's ρ rank correlation. A surrogate split for node number one is the functional class of the street the UIC device is located on (agreement=82%).

Table 6. Summary output for node number one of UIC contributing area characteristic regression tree from 'R'.

Primary Splits for Node #1	Improvement in Impurity Index
Surface area of utility poles surrounded by concrete	0.4079
Number of utility poles surrounded by concrete	0.3898
Minimum distance from a utility pole to the catch basin inlet	0.2285
Total surface area of all utility poles in contributing area	0.2255
Ratio of utility pole surface area to UIC contributing area	0.1618

Nonparametric Data Analysis

The Mann-Whitney U test ($\alpha=0.05$) confirmed the results of Kennedy/Jenks (2009) that PCP concentration in stormwater from UIC devices located on streets with greater than 1,000 vehicles per day (median=0.35 $\mu\text{g/L}$, mean=1.37 $\mu\text{g/L}$) is significantly different ($p\text{-value} < 0.001$) than stormwater from UIC devices located on streets with less than 1,000 vehicles per day (median=0.04 $\mu\text{g/L}$, mean=0.09 $\mu\text{g/L}$). *FIGURE 23* shows the distribution of PCP concentration in stormwater samples from streets with less than 1,000 trips per day and streets with greater than 1,000 trips per day.

Figure 22. Boxplot of pentachlorophenol concentration ($\mu\text{g/L}$) for streets with less than 1,000 vehicle trips per day and greater than 1,000 trips per day. $N=30$ for streets with less than 1,000 vehicle trips per day and $n=31$ for streets with greater than 1,000 vehicle trips per day (one site sampled twice). Significant differences ($\alpha=0.05$) in PCP concentration were found between sites located on streets with >1000 trips (b) per day and <1000 trips per day (a). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is $0.04\mu\text{g/L}$. Non-detects are reported at this concentration.

However, a Kruskal-Wallis rank sum test ($\alpha=0.05$) found no significant differences (p -value=0.29) in PCP concentrations between the three functional classes with greater than 1,000 vehicle trips per day (FIGURE 23).

Figure 23. Boxplot of PCP concentration by street functional class. All streets in the residential functional class (n=30) have less than 1,000 vehicle trips per day. The arterial (n=13), boulevard (n=5), and collector (n=13) functional classes (sum of n=31) have greater than 1,000 vehicle trips per day. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. The method reporting limit for PCP is 0.04µg/L. Non-detects are reported at this concentration.

While this study concurs with Kennedy/Jenks (2009) that streets with higher numbers of vehicle traffic per day have greater concentrations of pollutants in stormwater, utility poles are the primary source of PCP in urban runoff. *FIGURE 24* demonstrates that there is a relationship between the number of utility poles in a given UIC contributing area and the traffic volume on that street.

Figure 24. Number of utility poles versus vehicle trips per day for 60 UIC contributing areas. Significant differences ($\alpha=0.05$) in the number of utility poles located on streets with >1000 trips per day (b) and <1000 trips per day (a) were found.

A Mann-Whitney U-test found a significant difference ($\alpha=0.05$, $p\text{-value} < 0.001$) in the number of utility poles between streets with greater than 1,000 trips per day (median=2.00 utility poles, mean=2.03 utility poles) and streets with less than 1,000 trips per day (median=0.00, mean=0.83).

19 UIC contributing areas had a PCP concentration below the detection limit of $<0.04\mu\text{g/L}$ and all are located on streets with less than 1,000 vehicle trips per day, or the residential functional class (FIGURE 15, UIC points denoted by a yellow point). Six contributing areas have utility poles present, but only one contributing area has a utility pole surrounded by concrete. The utility poles located in the other five contributing areas are surrounded by either a soil or vegetative substrate. Additionally, three of the six sites have a minimum distance from utility pole to catch basin inlet of greater than 100 feet.

Spearman's ρ Rank Correlation

Spearman's ρ (rho) rank correlation coefficient was calculated using only those contributing areas with utility poles, for a total of $n=41$ sites. Based on the results of the regression tree analysis for UIC contributing areas (See *TABLE 6*), Spearman's ρ was calculated for eight UIC contributing area characteristics. The results are presented in *TABLE 7* below.

Table 7. Spearman's ρ rank correlation coefficient (bolded values are significant at $\alpha=0.05$) for various UIC device contributing area characteristics to determine correlations with pentachlorophenol concentration in stormwater. Only those contributing areas with utility poles present were used in the calculations ($n=41$). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011.

	ρ	p-Value
Average distance from utility poles to the street curb (ft)	0.07613	0.636
Total surface area for all utility poles (ft ²)	0.61553	<0.001
Total surface area for utility poles set in concrete (ft ²)	0.76108	<0.001
Minimum distance from a utility pole to the catch basin inlet (ft)	-0.5258	<0.001
Maximum distance from a utility pole to the catch basin inlet (ft)	0.10587	0.510
Average distance from utility poles to the catch basin inlet (ft)	-0.05567	0.729
Total distance from all utility poles to the catch basin inlet (ft)	0.14623	0.362
Ratio of utility pole surface area to UIC contributing area	0.4564	0.003

The scatter plots of total utility pole surface area (ft²) for a UIC device contributing area versus PCP concentration ($\mu\text{g/L}$) (*FIGURES 26a & b*), shows a positive relationship between utility pole surface area and PCP concentration in stormwater.

Figure 25a & 25b. Scatter plot of surface area (ft²) for all poles in a UIC device contributing area versus pentachlorophenol concentration (ug/L). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. **a)** Symbols are representative of rainfall during the stormwater sample collection event. Only contributing areas with utility poles present are included in the scatter plot (n=41). **b)** Symbols are representative of street functional class. Contributing areas with and without utility poles are included in this scatter plot only (n=61).

This is confirmed by Spearman's ρ rank correlation coefficient (p -value= <0.001 , $\rho=0.62$) at the 95% confidence level (*TABLE 7*). Additionally, *FIGURE 25a* shows that rainfall intensity during sample collection can be a factor in determining PCP concentration in stormwater. Three UIC contributing areas have approximately 600 ft² of utility poles. The site sampled during a heavy rainfall event (denoted by a diamond symbol) has the highest PCP concentration, followed by the site sampled during a moderate rainfall event (square symbol). The site sampled when it was not raining (circle symbol) has the lowest PCP concentration of the three. *FIGURE 25b*, which includes all 61 sites in the study, not just those with utility poles present, further demonstrates that street classes with higher volumes of traffic also have a greater total surface area of utility poles, and in some cases, higher concentrations of PCP in stormwater.

FIGURE 26 depicts a scatterplot of the total surface area (ft²) for all utility poles surrounded by concrete for a given contributing area against PCP concentrations in stormwater.

Figure 26. Scatter plot of surface area (ft²) of utility poles set in concrete in a UIC device contributing area versus pentachlorophenol concentration (µg/L). Symbols are representative of rainfall during the stormwater sample collection event. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. Only contributing areas with utility poles present were included in the scatter plot (n=41).

As with total utility pole surface area, the PCP concentration in stormwater appears to increase as the surface area for utility poles surrounded by concrete increases. This is also confirmed by Spearman's ρ rank correlation coefficient ($p\text{-value} < 0.001$, $\rho = 0.76$) at a 95% confidence interval (TABLE 7). FIGURE 26 again shows that rainfall intensity during sample collection could be an influential factor in PCP concentration in stormwater. There are three sites with low PCP concentrations in stormwater that were sampled during light intensity and no rain conditions with utility pole surface area greater than 500 ft² surrounded by concrete. However, other sites

with greater than 500ft² of utility pole surface area surrounded by concrete sampled during higher intensity storm events have a concentration of PCP in stormwater exceeding 5µg/L.

A third scatter plot was created to determine if there is a relationship between the minimum distance from a utility pole in a UIC contributing area to the catch basin inlet and PCP concentration in stormwater (*FIGURE 27*).

Figure 27. Scatter plot of minimum distance from a utility pole to the catch basin inlet versus pentachlorophenol concentration (µg/L) in a UIC device contributing area. Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. Only contributing areas with utility poles present were included in the scatter plot (n=41).

As the minimum distance from a utility pole to the catch basin inlet decreases, the PCP concentration in stormwater tends to increase. This negative correlation is confirmed by the Spearman's ρ rank correlation coefficient (p-value=<0.001, ρ =-0.53) at the 95% confidence interval (*TABLE 7*).

Spearman's ρ rank correlation coefficient was also calculated for the average distance from utility poles to the street curb, total distance from all utility poles to the catch basin inlet, average distance from the utility poles to the catch basin inlet, and maximum distance from a utility pole to the catch basin inlet to determine if there were any correlations with PCP concentration in stormwater. At the 95% confidence level, there were no significant correlations between any of these characteristics and PCP concentration in stormwater for UIC device contributing areas (*TABLE 7*).

Spatial Data Analysis

Site UIC-045 was the only site sampled two times during the 2009-2010 wet weather study, once during a heavy rain event (PCP concentration = 6.89 $\mu\text{g/L}$) and once during a light rain event (PCP concentration = 0.66 $\mu\text{g/L}$). The Global Moran's I was calculated twice in ArcGIS, once with each PCP concentration for site UIC-045 to maintain spatial balance. With the high concentration of PCP at site UIC-045, there was statistically significant ($\alpha=0.05$) positive spatial autocorrelation (p-value=0.035, z-score=2.11), or clustered concentrations of PCP. There was no significant positive or negative spatial autocorrelation (p-value=0.437, z-score=-0.78) when the lower PCP concentration from site UIC-045 was used.

The graphic output from the Anselin Local Moran's I using the higher PCP concentration for site UIC-045 is presented in *FIGURE 28a*. Red points denote clusters of high or low PCP concentrations while blue points denote PCP concentrations that are dispersed, or unlike neighboring sample sites. Clustered PCP concentrations are present on SE Stark Street, where there are multiple sites with higher concentrations of PCP. Dispersed PCP concentrations seem

to be present on streets with lower traffic volumes, where a sample with a high concentration of PCP is surrounded by samples with lower concentrations or vice versa.

The Getis-Ord General G tool was also calculated twice under the same conditions listed above. There was significant clustering ($\alpha=0.05$) of high concentrations of PCP in stormwater contributing areas when the higher value for UIC-045 was used (p-value=0.001, z-score=3.20). There was no significant clustering of high or low values when the lower PCP concentration from site UIC-045 was used (p-value=0.394, z-score=0.852).

The graphic output from the Getis-Ord Gi* using the higher PCP concentration for site UIC-045 is presented in *FIGURE 28b*. The red points represent hot spots, or statistically significant clustering of high values of PCP concentration in stormwater. The majority of hot spots are located on SE Stark Street. There were no cold spots, or statistically significant clusters of sample points with low PCP concentrations, found in the analysis.

Figure 28a & 28b. Results from **a)** the Anselin Local Moran's I cluster and outlier analysis (top) and **b)** Getis-Ord Gi* hot spot analysis (bottom). Water quality data is taken from the 2009-2010 Gresham Wet Weather study. Utility pole data was collected during August-November 2011. Maps created in ArcGIS Version 10.0.

DISUCSSION

The goal of this study is to identify significant characteristics of UIC contributing areas, specifically characteristics of utility poles, that could be used as predictors of high PCP concentration in stormwater. Although there is a considerable amount of variation between the 60 UIC contributing areas and 86 utility poles included in the study, there are some patterns that can be distinguished to aid in future management decisions.

Kennedy/Jenks (2009) demonstrated that streets with greater than 1,000 vehicle trips per day have higher pollutant loads, including PCP, than streets with less than 1,000 trips per day. This study also found statistically significant differences ($\alpha=0.05$) between the traffic classes. Beyond that, it is less certain if certain street functional classes that fall in the “greater than 1,000 vehicle trips per day” category should be monitored to a greater extent. *FIGURE 25b* indicates that boulevards and arterials may have higher PCP concentrations in runoff than collectors, and sampling emphasis could be placed on these functional classes. For example, only four sample points were taken from the functional class “boulevard” (all locations on SE Stark Street), however three of the four samples exceeded the current SDWA MCL for PCP.

The spatial analysis also supports the fact that higher traffic streets have greater concentrations of PCP in stormwater. The Local Moran’s I indicates that high concentrations of PCP in stormwater are clustered on SE Stark Street near the intersection with E Burnside Street. The spatially dispersed points are also located on or near SE Stark Street, where a high concentration of PCP in stormwater is located closer to lower concentrations of PCP in stormwater samples collected on smaller streets (*FIGURE 28a*). The hot spot analysis (*FIGURE*

28b) further confirms that the highest concentrations of PCP in stormwater are located on or near SE Stark Street.

Utility poles on SE Stark Street tend to have a surface area greater than 150 ft² and be surrounded by a concrete substrate. Most of the utility poles have also been inspected in the last 10 years and have had additional treatment compound infused (assumed by the presence of plastic diffusion plugs). Spearman's ρ rank correlation (*TABLE 7*) determined that there is a significant positive correlation ($\alpha=0.05$) between utility pole surface area and PCP concentration in stormwater. Nonparametric comparisons also determined that poles surrounded by concrete lead to a significantly ($\alpha=0.05$) higher concentration of PCP in stormwater. This is also true for poles with plastic diffusion plugs present. These three factors could explain why high PCP concentrations are clustered on SE Stark Street.

Fundamentally, the source of PCP in stormwater runoff is PCP treatment compound that has leached from wood utility poles. It doesn't have much to do with the amount of traffic on a particular street. *FIGURE 24* shows a statistically significant difference ($\alpha=0.05$) between the number of utility poles located in UIC contributing areas for sites with greater and less than 1,000 vehicle trips per day. Street class can be used as a proxy for the quantity or total surface area of utility poles, but focus should be placed on documenting the characteristics of the utility poles to gain a full understanding of the potential for high PCP concentrations in stormwater.

General characteristics of residential street classes also explain this seeming correlation between street class and number of utility poles in a UIC contributing area. A residential neighborhood is more likely to have tree courts or grassy strips where utility poles could be installed. They are also more likely to have a shorter height and smaller total surface area

(mean height_{<1000 TPD} = 39.56 ft, mean surface area_{<1000 TPD} = 115.39 ft²; mean height_{>1000 TPD} = 48.34 ft, mean surface area_{>1000 TPD} = 163.32 ft²).

The results of the regression tree analysis for utility pole characteristics indicate that the substrate surrounding the utility pole is the most important indicator of PCP in runoff. This corroborates the findings of the regression tree analysis for contributing area characteristics that total surface area of utility poles surrounded by concrete is the most important indicator of PCP in runoff. For future analysis of contributing area characteristics, it may be easiest to identify the presence or absence of utility poles surrounded by concrete, or the number of poles per basin set in concrete rather than measure the total surface area of each pole.

Other results from the regression tree analysis for utility pole characteristics conclude that the presence of ground staining, age of pole, and visual estimation of treatment compound on the pole could be indicators of high concentration of PCP in runoff. Multi-collinearity likely exists between these variables, especially if the presence and type of diffusion plugs in the pole is taken into account. When plastic diffusion plugs are present, it indicates that additional treatment compound has been injected into the pole in the past 12 years. Likely, this would lead to an increased amount of product leaching from the pole and staining the ground around it.

Additional significant factors identified in this study are minimum distance from the utility pole to the catch basin inlet, total surface area of all utility poles set in concrete in the contributing area, and amount of treatment product visible on the pole. These findings are similar to findings by GSI Water Solutions, Inc. (2011a) of important utility pole characteristics to use as indicators of PCP concentration in stormwater for 70 contributing areas in Portland.

They derived an empirical equation to relate the PCP concentration of stormwater to the total surface area of poles set in concrete, distance from a catch basin, and surface staining. The most weight was given to the total surface area of poles set in concrete, so that if there were no poles in concrete the equation was equal to zero (GSI, 2011a). This supports the outcome of the two exploratory regression trees, which both determined that utility poles surrounded by concrete were the most significant variable contributing to PCP concentration in stormwater.

A final factor that can affect the amount of PCP treatment compound leaching from utility poles, and thus the concentration of PCP in stormwater is the intensity of the rainfall event and the volume of runoff entering the catch basin inlet. *FIGURES 25a* and *26* graphically show that the two highest concentrations of PCP in stormwater samples from the 2009-2010 Wet Weather Study were collected during a storm with heavy rainfall intensity.

Limitations of the Study

Although this study included 60 UIC device contributing areas, the biggest limitation was the relatively small set of water quality data and the time lapse from when the water quality data was collected and when the utility pole data was collected. A major assumption of the study was that the utility poles located in the 60 sites were in the same condition that they were during the 2009-2010 sample collection. This is probably true for the most part. The last known inspection, when additional treatment compound could be injected into poles, was conducted in 2008 (based on the presence of inspection tags on the poles). However, there was one pole manufactured in 2009 (located in contributing area of UIC-094, PCP concentration = 0.884 µg/L) and one in 2010 (located in contributing area of UIC-015, PCP concentration =

0.449 $\mu\text{g/L}$). It is hard to say when these poles were installed, or what affect they may be having on the PCP concentration in stormwater for those contributing areas.

All comparisons between utility pole or contributing area characteristics were made with only one sample point of PCP concentration. These samples were collected over three months during varying rain intensities, which proved to be a potentially significant factor in the concentration of PCP. UIC-037 was sampled twice because illegally dumped oil was found in the catch basin during the first sample collection. Both concentrations were close to the detection limit, so a PCP concentration of 0.04 $\mu\text{g/L}$ was used in this study. This site, however, did not contain any utility poles.

Site UIC-045, located on SE Stark Street, was the other site sampled twice during the 2009-2010 wet weather study. This was done to verify the high concentrations of PCP found along SE Stark Street. The sample collected during heavy rainfall had a PCP concentration of 6.89 $\mu\text{g/L}$ while the sample collected during light rainfall had a PCP concentration of 0.659 $\mu\text{g/L}$, an order of magnitude difference. The samples also exceed the SWDA MDL in once circumstance and not in the other. Because this was the only site used in the present study with two PCP concentration points, the samples were considered as two distinct data points and a mean was not calculated. The exception was in the spatial analysis, where all tests were run twice. It would have been useful to have multiple samples from each site so that a geometric mean of the PCP concentration could be calculated and used to make comparisons.

Due to the nature of the data, non-parametric statistical analysis had to be used. These tests are not very powerful compared to their parametric counterparts. It is also difficult to determine which variable is the best predictor for PCP concentration in runoff because multiple

regression was not used. Additionally, many of the categorical data sets did not have sufficient numbers in each group to make statistical comparisons between groups. For example, the study found 48 poles manufactured by PentaFIR but only 10 poles manufactured by Taylor Treating, 4 manufactured by DFP, and 2 manufactured by McFarlane Cascade.

RECOMMENDATIONS

DEQ is in the process of updating the UIC WPCF Municipal Permit Template to reflect the findings of the GSI, Inc. (2011a) report and the maximum discharge limit for PCP will likely change to an effluent discharge limit equal to 10 µg/L, it is still important to monitor the concentration of this pollutant in stormwater due to its variability and potential to impact groundwater resources.

The findings of this study suggest that contributing areas with utility poles surrounded by concrete on streets with greater than 1,000 vehicle trips per day have the potential to have greater concentrations of PCP in runoff. Again this apparent correlation between street class and utility pole characteristic should be questioned and future data collection should focus on utility pole characteristics. The streetview function in GoogleEarth could be a useful tool to estimate the extent of utility poles set in concrete in other UIC contributing areas, beginning with high traffic streets. GoogleEarth could also be used to visually estimate the height of the pole (based on the categories in the Methods Section above), which could give an idea of the total surface area.

Given the significantly higher concentrations of PCP in stormwater when utility poles are surrounded by concrete, when new sidewalks are constructed or existing sidewalks are

repaired on high traffic streets maintain a buffer of soil or vegetation around the pole. This may already be occurring, based on the findings in the contributing area for UIC-011 (3048-W-098, E. Burnside and 177th, PCP concentration from 2009-2010 study = 0.827µg/L; *FIGURE 29*). This practice could also occur when new utility poles are installed to replace unsafe poles or to retrofit older pole sites in known high PCP concentration contributing areas.

Figure 29. Utility pole located around E. Burnside and NE 177th Ave. outside of Providence Elder Care building. Sidewalk appears to be new with pervious surface left around the majority of the pole.

The local water table should be ten feet below the bottom of a UIC, if the runoff from utility poles is allowed to infiltrate around the pole there should be enough vertical separation for any PCP to attenuate before it would reach groundwater. It should also reduce the total amount of PCP in stormwater entering the UIC, as contributing areas with no poles set in concrete have significantly less PCP in runoff than contributing areas with utility poles set in concrete. This recommendation will likely require collaboration between multiple departments,

jurisdictions, and agencies, but the outcome will be safe, clean groundwater for future beneficial use.

Additionally, UIC devices located on SE Stark Street, particularly in the area east of the intersection with E Burnside Street, should to be monitored more frequently. High concentrations of PCP in stormwater are clustered in this area, and the groundwater table varies from 10-50 (*FIGURE 7*). This could be a potential area of concern for groundwater contamination if the parameters of the Fate and Transport tool or BIOSCREEN model are exceeded (See Previous Studies: GSI Water Solutions Report (2011b) for additional information).

Multiple samples should be collected from UIC devices during varying rain intensities to get an accurate representation of the variation in PCP concentration. *FIGURE 26* depicts that multiple sites with the surface area of utility poles surrounding concrete exceeding 400 ft² had lower concentrations of PCP in stormwater. These same sites were sampled during light intensity rain events or when it was not raining at all, and may have the potential to leach more PCP during higher rain intensity events. It may also be prudent to sample during summer storm events to see if higher concentrations of PCP are present after it is allowed to “build up” on the utility pole.

Spearman’s ρ detected a statistically significant correlation ($\alpha=0.05$) between pole surface area in a UIC contributing area and PCP concentration in stormwater samples (*TABLE 7*), and it may be prudent to verify that utility poles located in other UIC contributing areas located on residential streets follow these trends. Again, GoogleEarth could be used to get an idea of pole characteristics instead of performing site visits.

Finally, given the findings and limitations of the current study, it seems crucial to collect more data both in terms of stormwater samples from the same and different UIC devices as well as the characteristics of utility poles in newly sampled contributing areas. The new sample points and concentrations can be incorporated into the existing GIS layer to see if spatial patterns change with more data points. Also geometric means can be calculated for each sample point, giving a better estimate of the average concentration of PCP entering a specific UIC device. This is similar to the current methods employed by the City of Portland to meet their WPCF permit requirements (Appendix A).

ACKNOWLEDGEMENTS

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I would also not have been able to complete this project without the support of my great, loving family; especially Jeremy, Norman, and Leeroy.

APPENDIX A

City of Portland Exploratory Study & Current Compliance Monitoring

The City of Portland received the first and only WPCF permit from ODEQ in June 2005 for its approximately 9,900 UIC devices. The majority of the Portland's UICs are located in east Portland where soils are more porous and have higher infiltration rates (Portland UICMP, 2006a). Prior to receiving the permit, the City of Portland conducted two pilot studies between 2003 and 2005 to characterize stormwater entering UIC devices and to estimate the number of samples that might exceed regulatory limits for a particular analyte. The estimations were then used to calculate the number of UICs that would need to be sampled annually in order to obtain statistically representative water quality data for the entire UIC network (Portland SAP, 2006b).

PCP exceeded the maximum allowable discharge limit (MADL) in the pilot studies 8.1% of the time. Because PCP is designated as a primary pollutant of concern by the EPA, Portland used this figure in the calculation of a representative sample size under the assumption that it will provide an adequate number of samples to evaluate analytes of less concern. The GRTS survey design was used to identify six panels of 15 sampling locations based on daily traffic volumes (greater than 1,000 trips per day and less than 1,000 trips per day). One panel is stationary and is sampled each year of the permit and the other five panels rotate and are sampled approximately every five years. Five stormwater samples are collected at each location during October to May and the geometric mean concentration is calculated for each analyte (Portland SAP, 2006b).

During fiscal year 2008-2009, five of the 30 sampling locations exceeded the MADL for PCP (1µg/L) based on the geometric mean concentration. 26 individual samples from 11 UIC locations exceeded the MADL for PCP. The WPCF permit allows the unsaturated zone of the

subsurface to act as a part of the water quality system as long as adequate vertical separation is present. Using the Groundwater Protection Demo (GWPD) tool to evaluate the reduction of a pollutant in the unsaturated zone, Portland has determined that a vertical separation distance of greater than 5 feet is protective of groundwater resources. Since the UIC devices that exceeded the MADL for PCP had adequate vertical separation, the groundwater was still protected in those areas. These results were similar to the previous three years of wet weather monitoring (Portland UICMP Annual Report, 2009).

APPENDIX B

Contributing Area Delineation Procedure & Example of Contributing Area Delineation Map

City of Gresham Maps & Data Services - Procedure

Watershed Delineation

Author: drf
Date: 8/25/10
Revised (date
and author):

Reviewer: Pam Nooyen
Date: August 26, 2010
Revised (date
and reviewer):

Purpose/Summary: create a watershed from a single point or points.

Process:

- Start mxd with general area you think will be included in watershed, add LiDAR
- Make graphic polygon of area to keep and convert to shapefile
- For all tool procedures accept the defaults unless otherwise noted.
- Clip DEM- L:\LIDAR\dem_be\dem_navd88. Clip it conservatively [toolbox\Data Management tools\Raster Processing \ RasterProccessing\Clip] using above created shapefile (You can always clip more later, you can't put it back) (example of naming conventions that may be given during the delineation process follow) **The clipped LiDAR DEM = "clip_dem"**
- Create Flow Direction from clipped LiDAR. [toolbox\Spatial Analyst Tools\Hydrology\Flow Direction] **FlowDirection: "clip_dem"="dem_flow"**
- Make Sink area from Flow Direction [\Hydrology\Sink] using Flow Direction **Sink: "dem_flow" = "sink_flow"**
- Create Fill [\Hydrology\Fill] using clipped LiDAR as Input surface raster **Fill: "clip_dem"="fill_sink"**
- Create second corrected Flow Direction using Fill as Input surface raster **Second flow Direction: "fill_sink" = "fill_flow2"**
- Input second Flow Direction into Flow Accumulation [\Hydrology\Flow Accumulation] **Flow accumulation: "fill_flow2" = "flow_accum"**

- Create Flow Length with second Flow Direction as the Input flow direction raster [Spatial Analyst Tools\Hydrology\Flow Length] Use:downstream
Flow Length : “fill_flow2” = “flow_length”
- Use Snap Pour Point [\Hydrology\Snap Pour Point] to set watershed basin starting points. Input a single or multiple points as a shapefile and Flow Accumulation. I used 50 ft for a snap distance.
Snap Pour Point: “flow_accum” = “pour_point”
- Create Watershed using second Flow Direction and Snap Pour Point shapefile. [Spatial Analyst Tools\Hydrology\Watershed]
Watershed: “fill_flow2” + “pour_point” = “new watershed”
- This is your Watershed. Convert raster watershed to polygon, [Toolbox\Conversion Tools\From Raster\Raster to Polygon]
- Now check that there are no other things happening to change the shape of the basin. Are there pipes and inlet/outlets running from outside or inside the basin to the other side of the boundary? If yes, then you are going to need to account for that by either adding to the Snap Pour Points for inlets or cutting out areas for outlets that drain outside the basin, possibly with arials and contours. Talk this portion over with the requestor of the watershed project.
- If you have to add more Snap Pour Points because of additional inlets outside of basin that are piped inside the basin, you will have to start at the Snap Pour Point and continue on through making an additional watershed polygon and Union the two polygons.
- Do you need to clip to City Limits? Or some other political boundary.
- Make sure you Recalculate Geometry if you need acreage or other total area figure.

APPENDIX C

Field Data Collection Sheet & Instructions

City of Gresham UIC - Power Pole Data Collection Sheet

DATE

FIELD TEAM

UIC DATA:	
UIC Unique ID#	
Catch Basin Type	
Depth of Sumped Area (inches)	
Sedimentation Manhole Present	

CROSS STREETS:

POWER POLE DATA:					
Power Pole Unique ID#					
Inlet to Pole Direction					
GPS Coordinates:	N45°	N45°	N45°	N45°	N45°
<i>latitude</i>					
<i>longitude</i>	W122°	W122°	W122°	W122°	W122°
Pole Circumference (inches)					
Pole Diameter (inches)					
Pole Height					
PGE Power Pole Map #					
PGE Power Pole #					
Pole Material (Manufacturer)					
Installation/Manufacture Date					
Inspection Tag Years					
Distance to UIC inlet (feet)					
Distance to Curb, if present					
Surface Immediately Surrounding Pole					
Distance to Nearest Impervious Surface					
Treatment Product Visible on Pole					
Treatment Compound on Ground					
Pole Appearance					
Diffusion Plugs Present					
<i># of plugs present</i>					

SURROUNDING AREA DATA:					
Adjacent Land Use					
Soil Type					

OTHER NOTES:

DATA SHEET INSTRUCTIONS

UIC DATA	
UIC Unique ID#	City of Gresham System ID
Catch Basin Type	S = Sumped U = Unsumped
Depth of Sumped Area	Measure depth in inches using a yard stick
Sedimentation Manhole Present	Y = Yes N = No

POWER POLE DATA	
Power Pole Unique ID	Number each power pole in the drainage basin sequentially using the GRTS rank number in the following format: UIC-###-PP1, etc.
GPS Coordinate	Latitude and longitude in WGS 84 units
Pole Circumference	Measure circumference at breast height using tape measure to the nearest 1"
Pole Diameter	Calculate pole diameter using the measured circumference
Pole Height	S = utility pole used for light only. 20-30' M = utility pole used for simple utility connections. May have one cross bar. 40-50' T = utility pole has 3+ transducers at top of pole. May have additional cross bar at a lower height. 50+
PGE Power Pole Map #	Record PGE map number listed on PGE ID tag, if present. Tag located on street face of pole.
PGE Power Pole #	Record PGE pole number listed on PGE ID tag, if present. Tag located on street face of pole.
Pole Manufacturer Information	Record pole material or manufacturer, if present. Tag located on either side of pole.
Pole Manufacture / Installation Year	Year manufactured will be on manufacturer tag. If not present, use year installed on PGE tag.
Inspection Tag Years	Record each year pole inspected.
Distance to UIC Inlet	Measure from pole to nearest catch basin to ± 3 feet. Measure along stormwater flow path parallel to curb or street.
Distance to Curb (if present)	Measure perpendicular from pole to edge of curb to ± 1 inch.
Surface Immediately Surrounding Pole	C = Wood to concrete V = Wood to vegetated surface (grass or weeds) D = Wood to dirt, gravel, bark chips A = Wood to asphalt O = Wood to other
Distance to Nearest Impervious Surface	Measure perpendicular from pole to nearest impervious surface ± 1 inch
Treatment Product Visible on Pole	H = Heavily treated: pole surface has runs, drips, seeps of wood treatment M = Medium: treatment apparent from staining, oily appearance L = No recent treatment apparent: gray and weathered appearance O = Other...describe in comments
Treatment Compound on Ground	Y = Yes N = No If yes, indicate radius of compound to ± 1 inch.
Pole Appearance	J = Juvenile: pole surface appears fairly smooth with uniform color. From appearance pole appears relatively young. M = Mature: age of pole can't be estimated. Pole surface appears slightly weathered, some cracking and color variation possible. Doesn't fit in one of the other categories W = Weathered: pole surface appears aged from color and cracked, splintered, and/or dry
Diffusion Plugs Present	Note whether diffusion plugs are present in the pole to indicate field treatment, material of the plugs if not plastic, and number of plugs

APPENDIX D

Comprehensive Utility Pole Data for 60 UIC Contributing Areas & Soil Complexes

GRTS Rank	Power Pole Unique ID	System ID	Penta (ug/L)	Catch Basin Type	Sed Manhole	Functional Class	GPS Latitude	GPS Longitude	Pole Circumference (ft)	Pole Height (ft)
UIC-001	UIC-001-PP1	3349-J-088	0.04	SUMPED	NO	RESIDENTIAL	N45°29.817'	W122°28.183'	1.31	33
UIC-002	UIC-002-PP1	3152-F-032	0.04	SUMPED	YES	RESIDENTIAL	N45°31.014'	W122°26.625'	3.08	45
	UIC-002-PP2						N45°31.051'	W122°26.621'	3.17	45
UIC-003	UIC-003-PP1	3047-W-004	0.348	SUMPED	NO	ARTERIAL	N45°31.580'	W122°29.442'	3.17	58
	UIC-003-PP2						N45°31.583'	W122°29.482'	3.08	58
	UIC-003-PP3						N45°31.583'	W122°29.521'	3	58
UIC-004	UIC-004-PP0	3748-W-029	0.0962	SUMPED	NO	RESIDENTIAL				
UIC-007	UIC-007-PP0	3047-W-032	0.0451	SUMPED	NO	RESIDENTIAL				
UIC-008	UIC-008-PP0	3249-W-045	0.0926	SUMPED	NO	RESIDENTIAL				
UIC-009	UIC-009-PP0	3050-W-057	0.04	SUMPED	NO	RESIDENTIAL				
UIC-010	UIC-010-PP1	3153-F-051	0.0939	SUMPED	NO	RESIDENTIAL	N45°31.053	W122°25.467'		33
	UIC-010-PP2						N45°31.025'	W122°25.495'	3.08	33
UIC-011	UIC-011-PP1	3048-W-098	0.827	SUMPED	NO	COLLECTOR	N45°31.328'	W122°28.776'	3.5	45
	UIC-011-PP2						N45°31.327'	W122°28.838'	3.5	45
	UIC-011-PP3						N45°31.325'	W122°28.868'		45
UIC-012	UIC-012-PP1	3249-W-048	1.06	SUMPED	YES	COLLECTOR	N45°30.274'	W122°28.069'	4.42	58
	UIC-012-PP2						N45°30.276'	W122°28.043'	2.17	45
UIC-013	UIC-013-PP0	3050-W-028	0.04	SUMPED	NO	RESIDENTIAL				
UIC-014	UIC-014-PP1	3153-F-041	0.162	SUMPED	NO	ARTERIAL	N45°30.798'	W122°26.022'	3.17	45
UIC-015	UIC-015-PP1	3149-W-079	0.884	UNSUMPED	YES	COLLECTOR	N45°31.132'	W122°28.088'	3.17	45
	UIC-015-PP2						N45°31.115'	W122°28.090'	3.67	45
	UIC-015-PP3						N45°31.112'	W122°28.087'	3	45
	UIC-015-PP4						N45°31.090'	W122°28.088'	3	45
	UIC-015-PP5						N45°31.056'	W122°28.078'	3.67	45
UIC-017	UIC-017-PP1	3449-J-006	0.04	SUMPED	NO	RESIDENTIAL	N45°29.704'	W122°28.168'	2.5	33
UIC-018	UIC-018-PP0	3151-F-054	0.04	SUMPED	NO	RESIDENTIAL				
UIC-019	UIC-019-PP1	2947-W-059	0.04	SUMPED	NO	RESIDENTIAL	N45°31.664'	W122°29.497'	2.17	33
	UIC-019-PP2						N45°31.663	W122°29.551'	2.17	33
	UIC-019-PP3						N45°31.657	W122°29.596	2.17	33
UIC-020	UIC-020-PP0	3348-W-015	0.04	SUMPED	NO	RESIDENTIAL				

GRTS Rank	Power Pole Unique ID	Surface Area (ft2)	PGE Power Pole Map	PGE Power Pole Number	Pole Manufacturer	Pole Manufacture Date	Last Inspection	Distance to UIC Inlet (ft)	Distance to Curb (ft)	Substrate Surrounding Pole
UIC-001	UIC-001-PP1	43.23	A1308B	1276				495	1.17	DIRT
UIC-002	UIC-002-PP1	138.6			PENTAFIR	1966	1989	225	2.08	DIRT
	UIC-002-PP2	142.65	D134A	7062	PENTAFIR	1965	1989	54	2.08	VEGETATION
UIC-003	UIC-003-PP1	183.86	A1331C	2990		1960	2008	10	1.33	CONCRETE
	UIC-003-PP2	178.64	A1331	2989	CREOFIR	1960	2008	157	1.25	CONCRETE
	UIC-003-PP3	174	A1331C	2988		1960	2008	310	1.33	CONCRETE
UIC-004	UIC-004-PP0									
UIC-007	UIC-007-PP0									
UIC-008	UIC-008-PP0									
UIC-009	UIC-009-PP0									
UIC-010	UIC-010-PP1	43.542474	D133A	12183		1978		81	1.25	OTHER
	UIC-010-PP2	101.64	D133B	14100		1986		171	1.58	DIRT
UIC-011	UIC-011-PP1	157.5	A1331D	502	DFP		2008	24	10	DIRT
	UIC-011-PP2	157.5	A1331	504	DFP		2008	189	14.58	DIRT
	UIC-011-PP3	0						321	11	DIRT
UIC-012	UIC-012-PP1	256.36	D1305C	1660	TAYLOR TREATING	1999	2008	15	0.83	CONCRETE
	UIC-012-PP2	97.65	D135C	4249	PENTAFIR	1984	2007	135	1.42	VEGETATION
UIC-013	UIC-013-PP0									
UIC-014	UIC-014-PP1	142.65	D137D	6342	PENTAFIR	1963	2007	66	7.25	DIRT
UIC-015	UIC-015-PP1	142.65	D135B	13598	PENTAFIR	1983	2007	18	1.17	CONCRETE
	UIC-015-PP2	165.15	D1305B	455	MCFARLANE CASCADE	2009		63	1.33	CONCRETE
	UIC-015-PP3	135	D135B	2001	PENTAFIR	1964	1989	114	1.33	CONCRETE
	UIC-015-PP4	135	D135B	236	PENTAFIR	1964	1989	255	1.08	CONCRETE
	UIC-015-PP5	165.15	D135B	3020	TAYLOR TREATING	1994		420	0.58	DIRT
UIC-017	UIC-017-PP1	82.5					1993	75	0.83	DIRT
UIC-018	UIC-018-PP0									
UIC-019	UIC-019-PP1	71.61	A1331B	5102	PENTAFIR	1973	1993	144	0.83	VEGETATION
	UIC-019-PP2	71.61	A1331B	5101	PENTAFIR	1973	1993	60	0.92	CONCRETE
	UIC-019-PP3	71.61	A1331B	5100	PENTAFIR	1973	1993	246	1.5	VEGETATION
UIC-020	UIC-020-PP0									

GRTS Rank	Power Pole Unique ID	Distance to Impervious Surface (ft)	Visual Est. of Product on Pole	Treatment Compound on Ground	Radius Treatment Compound Ground (in)	Pole Appearance	Diffusion Plugs Present	Number Diffusion Plugs	Adjacent Land Use	Soil Complex
UIC-001	UIC-001-PP1	0.58	LOW	NO		WEATHERED	NO		RESIDENTIAL	29A
UIC-002	UIC-002-PP1	1.58	MEDIUM	YES	2	MATURE	WOOD	3	RESIDENTIAL	26B
	UIC-002-PP2	1.67	MEDIUM	NO		WEATHERED	WOOD	2	RESIDENTIAL	26B
UIC-003	UIC-003-PP1	NA	HIGH	NO		MATURE	PLASTIC	5	RESIDENTIAL	30A
	UIC-003-PP2	NA	LOW	NO		WEATHERED	PLASTIC	4	RESIDENTIAL	30A
	UIC-003-PP3	NA	MEDIUM	YES	1.5	MATURE	PLASTIC	5	RESIDENTIAL	30A
UIC-004	UIC-004-PP0									30A
UIC-007	UIC-007-PP0									30A
UIC-008	UIC-008-PP0									30A
UIC-009	UIC-009-PP0									30A
UIC-010	UIC-010-PP1	0.71	LOW	NO		WEATHERED	NO		RESIDENTIAL	25B
	UIC-010-PP2	1.08	LOW	NO		WEATHERED	NO		RESIDENTIAL	25B
UIC-011	UIC-011-PP1	6	HIGH	NO		MATURE	PLASTIC	5	COMMERCIAL	30A
	UIC-011-PP2	6.25	MEDIUM	NO		MATURE	PLASTIC	5	COMMERCIAL	30A
	UIC-011-PP3	5	MEDIUM	NO		MATURE	PLASTIC		RESIDENTIAL	30A
UIC-012	UIC-012-PP1	NA	MEDIUM	NO		JUVENILE	PLASTIC	4	RESIDENTIAL	30A
	UIC-012-PP2	0.92	MEDIUM	NO		MATURE	PLASTIC	4	RESIDENTIAL	30A
UIC-013	UIC-013-PP0									30A
UIC-014	UIC-014-PP1	1.25	MEDIUM	NO		WEATHERED	PLASTIC	4	RESIDENTIAL	26B
UIC-015	UIC-015-PP1	NA	MEDIUM	YES	4	WEATHERED	PLASTIC	3	COMMERCIAL	30A
	UIC-015-PP2	NA	HIGH	YES	10	JUVENILE	NO		RESIDENTIAL	30A
	UIC-015-PP3	NA	LOW	NO		WEATHERED	WOOD	4	RESIDENTIAL	30A
	UIC-015-PP4	NA	MEDIUM	NO		WEATHERED	WOOD	4	RESIDENTIAL	30A
	UIC-015-PP5	0.08	MEDIUM	YES	1	MATURE	NO		RESIDENTIAL	30A
UIC-017	UIC-017-PP1	0.25	LOW	NO		WEATHERED	NO		RESIDENTIAL	29A
UIC-018	UIC-018-PP0									26B
UIC-019	UIC-019-PP1	2.17	MEDIUM	YES	9	WEATHERED	WOOD	3	RESIDENTIAL	30A
	UIC-019-PP2	NA	LOW	NO		MATURE	WOOD	3	RESIDENTIAL	30A
	UIC-019-PP3	1.08	LOW	NO		MATURE	WOOD	3	RESIDENTIAL	30A
UIC-020	UIC-020-PP0									30A

GRTS Rank	Power Pole Unique ID	System ID	Penta (ug/L)	Catch Basin Type	Sed Manhole	Functional Class	GPS Latitude	GPS Longitude	Pole Circumference (ft)	Pole Height (ft)
UIC-021	UIC-021-PP1	3055-B-027	0.504	SUMPED	NO	ARTERIAL	N45°31.279'	W122°24.775'	3.5	45
	UIC-021-PP2						N45°31.255'	W122°24.758'	3.83	45
	UIC-021-PP3						N45°31.223'	W122°24.744'	3.83	45
UIC-022	UIC-022-PP1	3153-F-021	0.147	SUMPED	NO	ARTERIAL	N45°31.067'	W122°26.040'	3.5	45
	UIC-022-PP2						N45°31.103'	W122°26.037'	4.08	45
UIC-023	UIC-023-PP1	3047-W-109	0.197	SUMPED	NO	COLLECTOR	N45°31.319'	W122°29.194'	3.92	58
UIC-024	UIC-024-PP1	3249-W-026	0.0597	SUMPED	NO	RESIDENTIAL	N45°30.489'	W122°28.835'	2.08	33
UIC-025	UIC-025-PP0	3050-W-050	0.04	SUMPED	NO	RESIDENTIAL				
UIC-028	UIC-028-PP1	3349-W-056	0.123	SUMPED	YES	ARTERIAL	N45°30.268'	W122°28.228'	3	33
	UIC-028-PP2						N45°30.259'	W122°28.211'	2.83	45
UIC-029	UIC-029-PP1	3150-F-010	0.133	SUMPED	NO	RESIDENTIAL	N45°30.882'	W122°27.514'	3.17	45
	UIC-029-PP2						N45°30.892'	W122°27.508'	3.42	45
	UIC-029-PP3						N45°30.908'	W122°27.510'	4.17	45
UIC-030	UIC-030-PP0	3152-F-082	0.04	SUMPED	YES	RESIDENTIAL				
UIC-031	UIC-031-PP1	3149-W-042	0.102	SUMPED	NO	RESIDENTIAL	N45°30.930'	W122°28.259'	2.92	45
UIC-032	UIC-032-PP0	2947-W-008	0.04	SUMPED	NO	RESIDENTIAL				
UIC-034	UIC-034-PP0	3152-F-050	0.04	SUMPED	NO	RESIDENTIAL				
UIC-035	UIC-035-PP1	2949-W-042	0.04	SUMPED	NO	RESIDENTIAL	N45°31.730'	W122°28.156'	2.83	45
	UIC-035-PP2						N45°31.733'	W122°28.122'	2.83	45
	UIC-035-PP3						N45°31.721'	W122°28.107'	2.92	33
UIC-036	UIC-036-PP1	3149-W-015	0.172	SUMPED	YES	COLLECTOR	N45°30.818'	W122°28.089'		33
UIC-037	UIC-037-PP0	3155-K-041	0.04	SUMPED	YES	RESIDENTIAL				
UIC-038	UIC-038-PP0	3052-F-020	0.04	SUMPED	YES	RESIDENTIAL				
UIC-039	UIC-039-PP1	3048-W-014	0.223	SUMPED	NO	ARTERIAL	N45°31.155'	W122°29.113'	3	58
UIC-040	UIC-040-PP0	3348-W-011	0.04	SUMPED	NO	RESIDENTIAL				
UIC-041	UIC-041-PP1	3149-W-019	2.6	SUMPED	NO	BOULEVARD	N45°31.142'	W122°28.014'	4.33	58
UIC-042	UIC-042-PP0	3152-F-058	0.04	SUMPED	NO	RESIDENTIAL				
UIC-043	UIC-043-PP0	3049-W-039	0.1	SUMPED	NO	RESIDENTIAL				
UIC-045	UIC-045-PP1	3050-W-019	6.89 / 0.659	SUMPED	NO	BOULEVARD	N45°31.151'	W122°27.672'	4.08	45
	UIC-045-PP2						N45°31.153'	W122°27.706	3	33
UIC-046	UIC-046-PP0	3048-W-081	0.04	SUMPED	NO	RESIDENTIAL				

GRTS Rank	Power Pole Unique ID	Surface Area (ft2)	PGE Power Pole Map	PGE Power Pole Number	Pole Manufacturer	Pole Manufacture Date	Last Inspection	Distance to UIC Inlet (ft)	Distance to Curb (ft)	Substrate Surrounding Pole
UIC-021	UIC-021-PP1	157.5	A1335C	3371		1990	2008	36	5.17	VEGETATION
	UIC-021-PP2	172.35	A1335C	3370	PENTAFIR	1990	2008	207	4.67	DIRT
	UIC-021-PP3	172.35	A1335C	3369	PENTAFIR	1990	2008	426	4.83	CONCRETE
UIC-022	UIC-022-PP1	157.5	D1303B	2579	TAYLOR TREATING	1997	2007	192	7.67	DIRT
	UIC-022-PP2	183.6	D1303B	3	TAYLOR TREATING	1996	2007	6	9.58	DIRT
UIC-023	UIC-023-PP1	227.36	A1331C	1610		1983	2002	111	2.92	CONCRETE
UIC-024	UIC-024-PP1	68.64	D1305C	8408	PENTAFIR	1971	1997	30	1.5	VEGETATION
UIC-025	UIC-025-PP0									
UIC-028	UIC-028-PP1	99			PENTAFIR	1968		66	1.08	VEGETATION
	UIC-028-PP2	127.35	D138	1967	PENTAFIR	1960	1989	66	18.42	VEGETATION
UIC-029	UIC-029-PP1	142.65	D135A	1589	PENTAFIR	1982		132	4.17	VEGETATION
	UIC-029-PP2	153.9	D1305A	3	PENTAFIR	1989	2007	57	4.17	DIRT
	UIC-029-PP3	187.65	D135	981	PENTAFIR	1982		36	3.92	DIRT
UIC-030	UIC-030-PP0									
UIC-031	UIC-031-PP1	131.4	D135B	6114	PENTAFIR	1962	1989	15	1.08	VEGETATION
UIC-032	UIC-032-PP0									
UIC-034	UIC-034-PP0									
UIC-035	UIC-035-PP1	127.35	A1332B	4834	PENTAFIR	1955	1993	321	1.25	DIRT
	UIC-035-PP2	127.35	A1332	2268	PENTAFIR	1955	1989	198	1.25	VEGETATION
	UIC-035-PP3	96.36	A1332B	4835	PENTAFIR	1955	1993	102	1.25	VEGETATION
UIC-036	UIC-036-PP1	0							16	DIRT
UIC-037	UIC-037-PP0									
UIC-038	UIC-038-PP0									
UIC-039	UIC-039-PP1	174	A1331D	3087	PENTAFIR	1975	2008	150	5.92	CONCRETE
UIC-040	UIC-040-PP0									
UIC-041	UIC-041-PP1	251.14	D135	478	PENTAFIR	1982	2002	96	4.83	CONCRETE
UIC-042	UIC-042-PP0									
UIC-043	UIC-043-PP0									
UIC-045	UIC-045-PP1	183.6	A1332D	1208	TAYLOR TREATING	1995	2002	12	1.42	CONCRETE
	UIC-045-PP2	99	A1332D	2755		1955	1993	120	5.33	CONCRETE
UIC-046	UIC-046-PP0									

GRTS Rank	Power Pole Unique ID	Distance to Impervious Surface (ft)	Visual Est. of Product on Pole	Treatment Compound on Ground	Radius Treatment Compound Ground (in)	Pole Appearance	Diffusion Plugs Present	Number Diffusion Plugs	Adjacent Land Use	Soil Complex
UIC-021	UIC-021-PP1	0.75	MEDIUM	NO		MATURE	PLASTIC	3	RESIDENTIAL	29A
	UIC-021-PP2	0.25	LOW	NO		MATURE	PLASTIC	5	RESIDENTIAL	29A
	UIC-021-PP3	NA	MEDIUM	YES	1	MATURE	PLASTIC	6	COMMERCIAL	29A
UIC-022	UIC-022-PP1	1.33	HIGH	NO		JUVENILE	PLASTIC	4	COMMERCIAL	26A
	UIC-022-PP2	3.17	HIGH	NO		JUVENILE	PLASTIC	7	COMMERCIAL	26A
UIC-023	UIC-023-PP1	NA	MEDIUM	YES	2	MATURE	PLASTIC	8	RESIDENTIAL	30A
UIC-024	UIC-024-PP1	1	HIGH	NO		MATURE	WOOD	4	RESIDENTIAL	30A
UIC-025	UIC-025-PP0									30A
UIC-028	UIC-028-PP1	0.67	MEDIUM	NO		WEATHERED	WOOD	1	RESIDENTIAL	30A
	UIC-028-PP2	18	MEDIUM	NO		WEATHERED	WOOD	2	RESIDENTIAL	30A
UIC-029	UIC-029-PP1	3.75	HIGH	NO		MATURE	NO		INDUSTRIAL	30A
	UIC-029-PP2	3.75	LOW	NO		MATURE	PLASTIC	4	INDUSTRIAL	30A
	UIC-029-PP3	3.17	HIGH	NO		MATURE	NO		INDUSTRIAL	30A
UIC-030	UIC-030-PP0									29A
UIC-031	UIC-031-PP1	0.67	LOW	NO		MATURE	WOOD	4	RESIDENTIAL	30A
UIC-032	UIC-032-PP0									30A
UIC-034	UIC-034-PP0									26B
UIC-035	UIC-035-PP1	0.75	LOW	NO		WEATHERED	WOOD	3	RESIDENTIAL	30A
	UIC-035-PP2	0.75	LOW	NO		WEATHERED	WOOD	3	RESIDENTIAL	30A
	UIC-035-PP3	0.75	MEDIUM	NO		MATURE	WOOD	3	RESIDENTIAL	30A
UIC-036	UIC-036-PP1	10	HIGH	YES	3	MATURE			COMMERCIAL	30A
UIC-037	UIC-037-PP0									29B
UIC-038	UIC-038-PP0									30B
UIC-039	UIC-039-PP1	NA	HIGH	YES	4	WEATHERED	PLASTIC	3	COMMERCIAL	30A
UIC-040	UIC-040-PP0									30A
UIC-041	UIC-041-PP1	NA	HIGH	YES	1	MATURE	PLASTIC	7	COMMERCIAL	30A
UIC-042	UIC-042-PP0									29A
UIC-043	UIC-043-PP0									30A
UIC-045	UIC-045-PP1	NA	MEDIUM	YES	3	MATURE	PLASTIC	5	COMMERCIAL	30A
	UIC-045-PP2	NA	MEDIUM	NO		WEATHERED	WOOD	2	COMMERCIAL	30A
UIC-046	UIC-046-PP0									30A

GRTS Rank	Power Pole Unique ID	System ID	Penta (ug/L)	Catch Basin Type	Sed Manhole	Functional Class	GPS Latitude	GPS Longitude	Pole Circumference (ft)	Pole Height (ft)
UIC-047	UIC-047-PP1	3149-W-059	0.354	SUMPED	YES	RESIDENTIAL	N45°31.043'	W122°28.541'	2.92	45
	UIC-047-PP2						N45°31.039'	W122°28.543'	3	15
	UIC-047-PP3						N45°31.057'	W122°28.545'	3.83	58
	UIC-047-PP4						N45°31.086'	W122°28.542'	4	58
UIC-048	UIC-048-PP1	2946-W-002	0.947	SUMPED	NO	ARTERIAL	N45°31.591'	W122°29.795'	4.75	58
	UIC-048-PP2						N45°31.590'	W122°29.835'	4.25	58
	UIC-048-PP3						N45°31.590'	W122°29.876'	4.75	58
	UIC-048-PP4						N45°31.592'	W122°29.907'	4.17	58
	UIC-048-PP5						N45°31.592'	W122°29.939'	4.25	58
UIC-049	UIC-049-PP1	3449-J-073	0.17	UNSUMPED	YES	RESIDENTIAL	N45°29.577'	W122°28.447'	2.5	33
	UIC-049-PP2						N45°29.575'	W122°28.533'	3.5	45
UIC-050	UIC-050-PP1	3250-F-007	0.9	SUMPED	NO	RESIDENTIAL	N45°30.636'	W122°27.507'	3	45
UIC-051	UIC-051-PP1	3047-W-027	5.74	SUMPED	NO	COLLECTOR	N45°31.269'	W122°29.168'	2.83	45
	UIC-051-PP2						N45°31.244'	W122°29.166'	4.5	58
UIC-052	UIC-052-PP1	3149-W-003	1.79	SUMPED	NO	ARTERIAL	N45°30.791'	W122°28.539'	4.33	58
	UIC-052-PP2						N45°30.819'	W122°28.534'	3	45
UIC-053	UIC-053-PP1	2950-W-063	0.04	SUMPED	NO	RESIDENTIAL	N45°31.828'	W122°27.546'	2.33	33
UIC-054	UIC-054-PP0	3053-F-020	0.08	SUMPED	NO	ARTERIAL				
UIC-055	UIC-055-PP1	3048-W-097	0.216	SUMPED	NO	COLLECTOR	N45°31.309'	W122°28.859'		58
	UIC-055-PP2						N45°31.313'	W122°28.817'	4.08	58
UIC-057	UIC-057-PP1	3050-W-016	9.1	SUMPED	NO	BOULEVARD	N45°31.155'	W122°27.734'	3.67	58
	UIC-057-PP2						N45°31.163'	W122°27.773'	3.5	45
	UIC-057-PP3						N45°31.152'	W122°27.782'	4.17	58
UIC-059	UIC-059-PP0	3049-W-069	0.0862	SUMPED	NO	BOULEVARD				
UIC-060	UIC-060-PP1	3047-W-096	0.518	SUMPED	NO	COLLECTOR	N45°31.327'	W122°29.711'	4.17	58
	UIC-060-PP2						N45°31.323'	W122°29.744'	2.5	58
	UIC-060-PP3						N45°31.318'	W122°29.754'	4.08	58
	UIC-060-PP4						N45°31.320'	W122°29.772'	2.5	58
UIC-061	UIC-061-PP1	3150-F-043	0.118	SUMPED	NO	COLLECTOR	N45°30.911'	W122°27.310'	4.17	58
UIC-062	UIC-062-PP1	3047-W-047	0.163	SUMPED	NO	COLLECTOR	N45°31.466'	W122°29.177'	2.5	45
UIC-070	UIC-070-PP1	3153-F-025	0.149	SUMPED	NO	ARTERIAL	N45°30.968'	W122°26.037'	3	33
UIC-071	UIC-071-PP1	3047-W-103	0.139	SUMPED	NO	COLLECTOR	N45°31.334'	W122°29.407'	3.17	45

GRTS Rank	Power Pole Unique ID	Surface Area (ft2)	PGE Power Pole Map	PGE Power Pole Number	Pole Manufacturer	Pole Manufacture Date	Last Inspection	Distance to UIC Inlet (ft)	Distance to Curb (ft)	Substrate Surrounding Pole
UIC-047	UIC-047-PP1	131.4	D13053	509	JH BAXTER	2002	2007	144	6.75	DIRT
	UIC-047-PP2	45					1997	138	5.42	DIRT
	UIC-047-PP3	222.14	D135B	1084	PENTAFIR	1976	2008	27	7.83	DIRT
	UIC-047-PP4	232	D135B	492	PENTAFIR	1976	2008	144	NA	VEGETATION
UIC-048	UIC-048-PP1	275.5	A1236	2759		1989	2008	2	1.25	CONCRETE
	UIC-048-PP2	246.5	A1236	2758	TAYLOR TREATING	1999	2008	167	1	CONCRETE
	UIC-048-PP3	275.5	A1236	2757		1948	2008	314	1.33	DIRT
	UIC-048-PP4	241.86	A1236	2756	TAYLOR TREATING	1992	2008	452	1.17	CONCRETE
	UIC-048-PP5	246.5	A1236	2992	PENTAFIR	1987	2008	593	3	VEGETATION
UIC-049	UIC-049-PP1	82.5	D138	11365		1976	1993	297	1	VEGETATION
	UIC-049-PP2	157.5	D138	3235	PENTAFIR	1986	2008	30	1.08	CONCRETE
UIC-050	UIC-050-PP1	135	D135		PENTAFIR	1982		78	22	CONCRETE
UIC-051	UIC-051-PP1	127.35	A1331	377	PENTAFIR	1968	2008	171	0.92	CONCRETE
	UIC-051-PP2	261	A1331D	553	DFP		2008	12	0.92	CONCRETE
UIC-052	UIC-052-PP1	251.14	D135B	579	PENTAFIR	1976	2008	150	1.17	CONCRETE
	UIC-052-PP2	135	D135	578	PENTAFIR	1968	1989	15	1	CONCRETE
UIC-053	UIC-053-PP1	76.89	A1332A	6326	PENTAFIR	1978	1993	105	1.25	DIRT
UIC-054	UIC-054-PP0									
UIC-055	UIC-055-PP1	0		1233				252		DIRT
	UIC-055-PP2	236.64	A1331	1232	PENTAFIR	1988	2002	72	14.08	DIRT
UIC-057	UIC-057-PP1	212.86	A1332D	1207	PENTAFIR	1989	2002	126	1.33	CONCRETE
	UIC-057-PP2	157.5	A1332D	64	MCFARLANE CASCADE	2008		24	1.67	CONCRETE
	UIC-057-PP3	241.86	A1332D	6867	PENTAFIR	1989	2002	69	1.92	CONCRETE
UIC-059	UIC-059-PP0									
UIC-060	UIC-060-PP1	241.86	A1331C	3815	PENTAFIR	1983	2002	36	2.67	DIRT
	UIC-060-PP2	145	A1331	6763	PENTAFIR	1983		141	2.33	CONCRETE
	UIC-060-PP3	236.64	A1331	1248	PENTAFIR	1983	2002	195	2.92	CONCRETE
	UIC-060-PP4	145	A1331	6762			1993	249	3	CONCRETE
UIC-061	UIC-061-PP1	241.86	D135A	5616	PENTAFIR	1984	2002	252	1.83	CONCRETE
UIC-062	UIC-062-PP1	112.5	A1331D	53	DFP	1998	2008	90	13	DIRT
UIC-070	UIC-070-PP1	99						225	13.5	DIRT
UIC-071	UIC-071-PP1	142.65	A1331	521	PENTAFIR	1983	2008	66	10.83	DIRT

GRTS Rank	Power Pole Unique ID	Distance to Impervious Surface (ft)	Visual Est. of Product on Pole	Treatment Compound on Ground	Radius Treatment Compound Ground (in)	Pole Appearance	Diffusion Plugs Present	Number Diffusion Plugs	Adjacent Land Use	Soil Complex
UIC-047	UIC-047-PP1	1.25	MEDIUM	YES	3	MATURE	PLASTIC	3	RESIDENTIAL	30A
	UIC-047-PP2	0.08	LOW	NO		WEATHERED	WOOD	5	RESIDENTIAL	30A
	UIC-047-PP3	2.42	HIGH	YES	2	WEATHERED	PLASTIC	6	RESIDENTIAL	30A
	UIC-047-PP4	5.67	HIGH	NO		MATURE	PLASTIC	8	RESIDENTIAL	30A
UIC-048	UIC-048-PP1	NA	MEDIUM	NO		WEATHERED	PLASTIC	8	COMMERCIAL	30A
	UIC-048-PP2	NA	LOW	YES	4	MATURE	PLASTIC	3	MIXED	30A
	UIC-048-PP3	0.92	LOW	NO		WEATHERED	PLASTIC	8	RESIDENTIAL	30A
	UIC-048-PP4	NA	HIGH	YES	2	MATURE	PLASTIC	5	RESIDENTIAL	30A
	UIC-048-PP5	2.5	HIGH	YES	3	MATURE	PLASTIC	8	MIXED	30A
UIC-049	UIC-049-PP1	0.5	LOW	NO		WEATHERED	NO		RESIDENTIAL	29B
	UIC-049-PP2	NA	HIGH	YES	1	MATURE	PLASTIC	4	COMMERCIAL	29B
UIC-050	UIC-050-PP1	NA	MEDIUM	YES	2	MATURE	NO		INDUSTRIAL	30A
UIC-051	UIC-051-PP1	NA	HIGH	NO		WEATHERED	PLASTIC	5	RESIDENTIAL	30A
	UIC-051-PP2	NA	HIGH	YES	2	MATURE	PLASTIC	4	RESIDENTIAL	30A
UIC-052	UIC-052-PP1	NA	HIGH	YES	6	MATURE	PLASTIC	8	RESIDENTIAL	29A
	UIC-052-PP2	NA	HIGH	YES	6	MATURE	WOOD	4	MIXED	29A
UIC-053	UIC-053-PP1	0.75	HIGH	YES	2	MATURE	WOOD	3	RESIDENTIAL	30A
UIC-054	UIC-054-PP0									26A
UIC-055	UIC-055-PP1	NA	MEDIUM	NO		MATURE	PLASTIC		RESIDENTIAL	30A
	UIC-055-PP2	5.75	HIGH	YES	4	MATURE	PLASTIC	8	RESIDENTIAL	30A
UIC-057	UIC-057-PP1	NA	MEDIUM	YES	1	MATURE	PLASTIC	6	COMMERCIAL	30A
	UIC-057-PP2	NA	MEDIUM	YES	3	JUVENILE	NO		COMMERCIAL	30A
	UIC-057-PP3	NA	MEDIUM	YES	2	MATURE	PLASTIC	8	COMMERCIAL	30A
UIC-059	UIC-059-PP0									30A
UIC-060	UIC-060-PP1	2.17	HIGH	YES	4	MATURE	PLASTIC	8	RESIDENTIAL	30A
	UIC-060-PP2	NA	MEDIUM	NO		WEATHERED	WOOD	4	RESIDENTIAL	30A
	UIC-060-PP3	NA	HIGH	YES	8	MATURE	PLASTIC	8	RESIDENTIAL	30A
	UIC-060-PP4	NA	HIGH	YES	2	MATURE	WOOD	3	MIXED	30A
UIC-061	UIC-061-PP1	NA	MEDIUM	YES	3	MATURE	PLASTIC	7	COMMERCIAL	30A
UIC-062	UIC-062-PP1	7.58	MEDIUM	YES	5	MATURE	NO		RESIDENTIAL	30A
UIC-070	UIC-070-PP1	0.58	LOW	NO		WEATHERED	NO		RESIDENTIAL	26A
UIC-071	UIC-071-PP1	0.33	HIGH	YES	4	WEATHERED	PLASTIC	5	RESIDENTIAL	30A

GRTS Rank	Power Pole Unique ID	System ID	Penta (ug/L)	Catch Basin Type	Sed Manhole	Functional Class	GPS Latitude	GPS Longitude	Pole Circumference (ft)	Pole Height (ft)
UIC-086	UIC-086-PP1	3153-F-017	5.96	UNSUMPED	NO	ARTERIAL	N45°31.138'	W122°25.978'	5	58
	UIC-086-PP2						N45°31.144'	W122°26.016'	3.83	45
	UIC-086-PP3						N45°31.122'	W122°26.019'	3.17	45
UIC-093	UIC-093-PP1	3150-F-047	2.04	SUMPED	NO	ARTERIAL	N45°31.143'	W122°27.393'	3.42	45
	UIC-093-PP2						N45°31.143'	W122°27.431'	3.67	45
UIC-094	UIC-094-PP1	3254-F-072	0.449	SUMPED	NO	COLLECTOR	N45°30.505'	W122°25.267'	2.5	33
	UIC-094-PP2						N45°30.486'	W122°25.273'	2.33	33
	UIC-094-PP3						N45°30.460'	W122°25.270'	2.33	33
	UIC-094-PP4						N45°30.436'	W122°25.270'	2.33	33
	UIC-094-PP5						N45°30.406'	W122°25.274'	2.83	33
UIC-100	UIC-100-PP0	3248-W-020	0.0926	SUMPED	NO	ARTERIAL				
UIC-103	UIC-103-PP1	3048-W-091	0.204	SUMPED	NO	COLLECTOR	N45°31.338'	W122°29.042'	3	45
	UIC-103-PP2						N45°31.346'	W122°29.065'	2.83	45

GRTS Rank	Power Pole Unique ID	Surface Area (ft2)	PGE Power Pole Map	PGE Power Pole Number	Pole Manufacturer	Pole Manufacture Date	Last Inspection	Distance to UIC Inlet (ft)	Distance to Curb (ft)	Substrate Surrounding Pole
UIC-086	UIC-086-PP1	290	D1303B	2437	TAYLOR TREATING	1996	2007	156	5.17	CONCRETE
	UIC-086-PP2	172.35	D1303B	7169	TAYLOR TREATING	1996	2007	1	4.67	CONCRETE
	UIC-086-PP3	142.65	D133B2	7846	PENTAFIR	1968	2007	123	1.08	CONCRETE
UIC-093	UIC-093-PP1	153.9	D1305A	1032	TAYLOR TREATING	1994		42	1.08	CONCRETE
	UIC-093-PP2	165.15	D1305	767	PENTAFIR	1965	1989	216	1	CONCRETE
UIC-094	UIC-094-PP1	82.5	D1303D	77	SJI NW	2010		3		ASPHALT
	UIC-094-PP2	76.89					1989	72	1.92	CONCRETE
	UIC-094-PP3	76.89			PENTAFIR	1967	1989	228	1.83	CONCRETE
	UIC-094-PP4	76.89			PENTAFIR	1967	1989	381	1.92	CONCRETE
	UIC-094-PP5	93.39			PENTAFIR	1964	1989	546	4	CONCRETE
UIC-100	UIC-100-PP0									
UIC-103	UIC-103-PP1	135	A1331D	509	PENTAFIR	1989	2008	99	7.75	DIRT
	UIC-103-PP2	127.35	A1331	510	PENTAFIR	1983	2008	288	3.17	CONCRETE

GRTS Rank	Power Pole Unique ID	Distance to Impervious Surface (ft)	Visual Est. of Product on Pole	Treatment Compound on Ground	Radius Treatment Compound Ground (in)	Pole Appearance	Diffusion Plugs Present	Number Diffusion Plugs	Adjacent Land Use	Soil Complex
UIC-086	UIC-086-PP1	NA	HIGH	YES	3	MATURE	PLASTIC	8	COMMERCIAL	26A
	UIC-086-PP2	NA	HIGH	YES	4	MATURE	PLASTIC	8	COMMERCIAL	26A
	UIC-086-PP3	NA	MEDIUM	YES	6	MATURE	PLASTIC	4	COMMERCIAL	26A
UIC-093	UIC-093-PP1	NA	MEDIUM	YES	5	MATURE	NO		COMMERCIAL	30A
	UIC-093-PP2	NA	LOW	NO		WEATHERED	WOOD	4	COMMERCIAL	30A
UIC-094	UIC-094-PP1	NA	HIGH	NO		JUVENILE	NO		RESIDENTIAL	30A
	UIC-094-PP2	NA	MEDIUM	NO		WEATHERED	WOOD	2	RESIDENTIAL	30A
	UIC-094-PP3	NA	MEDIUM	NO		MATURE	WOOD	2	COMMERCIAL	30A
	UIC-094-PP4	NA	LOW	NO		WEATHERED	WOOD	3	COMMERCIAL	30A
	UIC-094-PP5	NA	MEDIUM	NO		MATURE	WOOD	2	COMMERCIAL	30A
UIC-100	UIC-100-PP0									30A
UIC-103	UIC-103-PP1	2.33	LOW	NO		MATURE	PLASTIC	5	RESIDENTIAL	30A
	UIC-103-PP2	NA	HIGH	YES	8	WEATHERED	PLASTIC	5	RESIDENTIAL	30A

Soil Complex	Soil Complex Name	Slope	A Horizon Soil Profile	B Horizon Soil Profile	C Horizon Soil Profile
25B	Latourell Loam	3-8%	Silt loam	Silt loam	Very gravelly sand
26A	Latourell Urban Land Complex	0-3%	Loam	Loam	Very gravelly sandy loam
26B	Latourell Urban Land Complex	3-8%	Loam	Loam	Very gravelly sandy loam
29A	Multnomah Silt Loam	0-3%	Silt loam	Silt loam	Very gravelly sand
29A	Multnomah Silt Loam	3-8%	Silt loam	Silt loam	Very gravelly sand
30A	Multnomah Urban Land Complex	0-3%	Silt loam	Silt loam	Very gravelly sand
30A	Multnomah Urban Land Complex	3-8%	Silt loam	Silt loam	Very gravelly sand

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