Reclaimed Water Infiltration Study
Task 1 Summary
Residual Chemicals in Reclaimed Water, Groundwater, and Surface Water

May 17, 2017

Background

The LOTT Clean Water Alliance (LOTT) manages wastewater for a population of approximately 108,000 in the urban areas of Lacey, Olympia, and Tumwater in Thurston County, Washington. Since 2006, LOTT has also produced reclaimed water, which is used for irrigation and other non-drinking purposes, or is sent to infiltration basins where it recharges groundwater. The long-range plan for meeting future wastewater needs has been centered on expanding reclaimed water production and groundwater recharge over time.

LOTT currently operates the following treatment facilities:

- Budd Inlet Treatment Plant (BITP), which discharges advanced secondary treated water to Budd Inlet, the southernmost portion of Puget Sound. At the same site, some of the water is sent to the Budd Inlet Reclaimed Water Plant (BIRWP) and treated to higher reclaimed water standards. Reclaimed water from this facility is used primarily for irrigation of parks, streetscapes, and a local golf course.
- Martin Way Reclaimed Water Plant (MWRWP), a satellite plant in Lacey that produces reclaimed water. Reclaimed water produced at this facility is used for groundwater recharge at two sites, including LOTT's Hawks Prairie Ponds and Recharge Basins (HPPRB).

Both the BIRWP and the MWRWP produce Class A Reclaimed Water, which is the highest quality of reclaimed water currently designated by the Washington State Departments of Ecology and Health. Class A Reclaimed Water is approved for almost all uses of water except drinking.

Purpose

LOTT is conducting a study to answer community questions and concerns about residual chemicals, such as pharmaceuticals, personal care products, and other organic chemicals, that may remain in reclaimed water after treatment and infiltration into the ground.

The goal of the Reclaimed Water Infiltration Study is to provide local scientific data and community perspectives to help policymakers make informed decisions about future reclaimed water treatment and uses. The multi-year study focuses on four study tasks:

- Task 1: Water Quality Characterization – analyze groundwater, surface water, wastewater, and reclaimed water for residual chemicals and other water quality indicators.
- Task 2: Treatment Effectiveness Evaluation – examine how infiltrated reclaimed water interacts with soils and local groundwater, and what happens to residual chemicals over time in the environment.
- Task 3: Risk Assessment – identify the relative risk to human and ecological health associated with infiltrating reclaimed water into groundwater.

- Task 4: Cost Benefit Analysis – calculate the costs and benefits of various levels of treatment for reclaimed water.

Task 1 of the study, completed in the spring of 2017, characterized the types of residual chemicals present in influent (untreated) wastewater, advanced secondary water treated at LOTT's BITP, reclaimed water produced at the BIRWP and MWRWP, local area groundwater, and local area surface water.

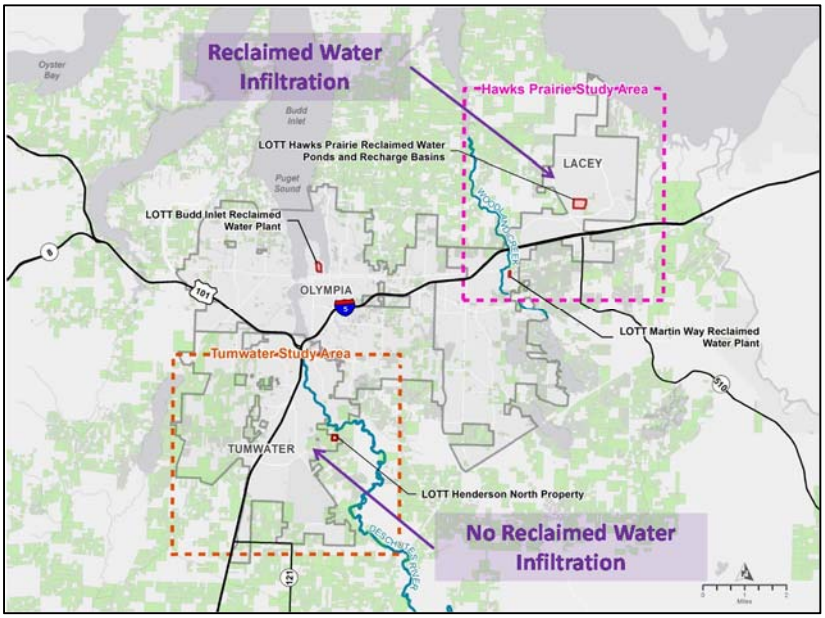
Methods

Water quality sampling was conducted over the course of approximately one year, from November 2014 to December 2015, in two study areas, both approximately 16 square miles in size (see **Figure 1**):

- The Hawks Prairie Study Area is located in the vicinity of north Lacey. LOTT's HPPRB are located within this study area. Infiltration of Class A Reclaimed Water has occurred in these recharge basins since 2006.
- The Tumwater Study Area is located in the vicinity of Tumwater. While reclaimed water has never been used for infiltration to groundwater within this study area, it is used for irrigation at several sites, and LOTT may develop an infiltration site in this area in the future.

Both study areas are characterized as having residential and rural-residential land uses, with moderate commercial activity. Portions of each study area are sewered, while other portions are served by on-site septic systems (as indicated by the green shading in **Figure 1**). Drinking water comes from groundwater, provided to some residents by public supply wells and to others by individual residential wells.

Figure 1. Study Areas



The following water quality samples were obtained in these study areas:

- **Wastewater/Reclaimed Water** – Sampling of influent wastewater (wastewater coming into the plants prior to treatment) and treated reclaimed water was conducted quarterly at the BITP, BIRWP, and MWRWP, to identify residual chemicals present in LOTT's wastewater and reclaimed water, and to assess the effectiveness of treatment performance on these chemicals.
- **Groundwater** – Single samples were obtained from each of the following: 33 residential wells, 22 public supply wells, one spring, and one monitoring well. The intent was to obtain a characterization of groundwater quality across a wide geography, and in both shallow and deep aquifers.
- **Surface water** – A total of 44 samples at 12 discrete sites were obtained from Woodland Creek and the Deschutes River and their tributaries. Samples were obtained at various times of the year to assess variability under different flow conditions: two samples during late summer low flow conditions, one sample after the first large fall storm, and one sample during winter high flow conditions.

These water samples were analyzed for a range of water quality parameters regulated in drinking water and wastewater and for 127 unregulated residual chemicals found in household products, pharmaceuticals, and personal care products. Most of these have been reported at very low concentrations (on the order of parts per trillion, or nanograms per liter) in previous studies of treated wastewater, groundwater, and surface waters. While tens of thousands of such chemicals exist in commonly used products, the chemicals tested as part of this study were selected specifically to include those that are:

- Representative of large classes of compounds,
- Commonly detected in reclaimed water,
- Routinely used in the wastewater industry for evaluating treatment effectiveness, and
- Reliably quantified in laboratory analysis.

Results

Regulated Parameters

Results of water quality testing showed that LOTT's two reclaimed water treatment facilities consistently produce high quality Class A Reclaimed Water that meets Washington State permit requirements with respect to conventional parameters, nutrient removal, and indicator bacteria reduction.

Groundwater quality was fairly consistent between the two study areas and reflected the general understanding of local area groundwater. Nitrate levels were below the drinking water quality standard of 10 mg/L, and ranged from non-detect up to 6.5 mg/L, with elevated concentrations mainly observed in areas served by residential on-site septic systems. Metals were below drinking water standards with the exception of one detection of arsenic, five detections of iron, and 14 detections of manganese above their respective maximum contaminant levels. Coliform bacteria were observed in 13 samples, with fecal coliform found in one of these.

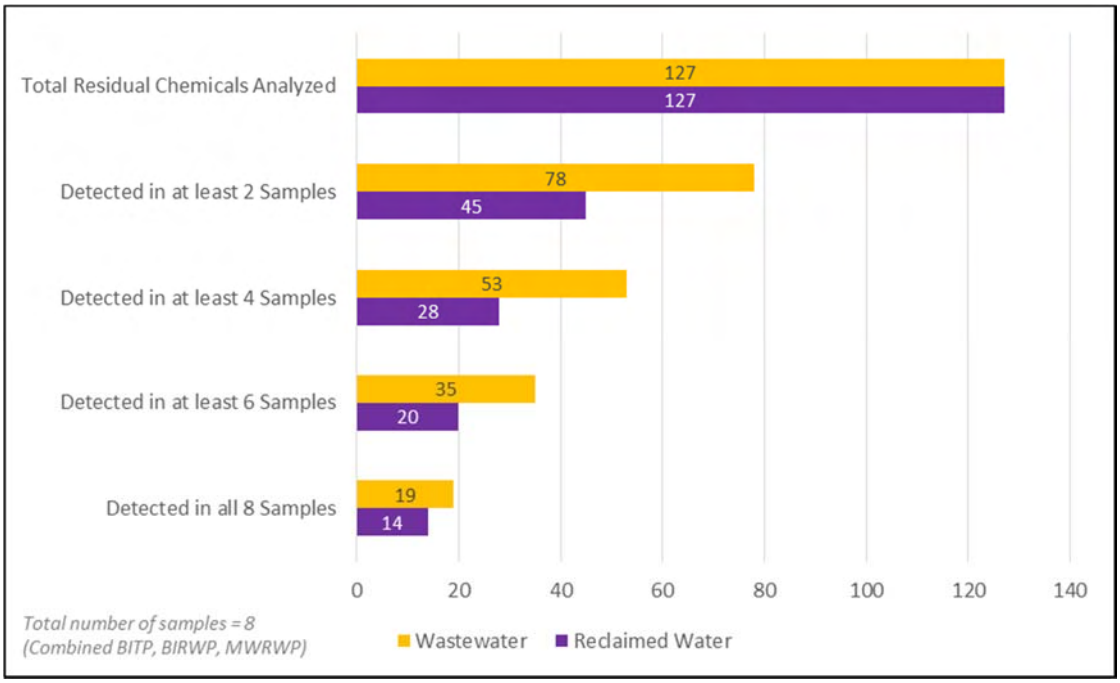
Surface water quality was consistent with results of previous studies. In Woodland Creek, state surface water quality standards were met, with the exception of some dissolved oxygen, pH, and fecal coliform concentrations. Nitrate levels averaged 1.5 mg/L in the creek, with the highest tributary concentrations reaching 3.3 mg/L in Beatty Springs. In the Deschutes River watershed, state surface water quality

standards were met, with the exception of low dissolved oxygen in Munn Lake, and high fecal coliform concentrations in Chambers and Percival Creeks. Nitrate concentrations in the Deschutes River were lower than in Woodland Creek, and were generally consistent with results of previous monitoring.

Residual Chemicals – Wastewater and Reclaimed Water

The occurrence of residual chemicals in the influent wastewater and treated reclaimed water was fairly consistent between the two facilities, in terms of the chemicals observed most frequently and their concentrations. **Figure 2** provides a summary of the number of residual chemicals observed in wastewater versus reclaimed water. Nineteen residual chemicals were detected in all eight samples of wastewater, while 14 were detected in all eight samples of reclaimed water.

Figure 2. Number of Residual Chemical Detections in Wastewater and Reclaimed Water

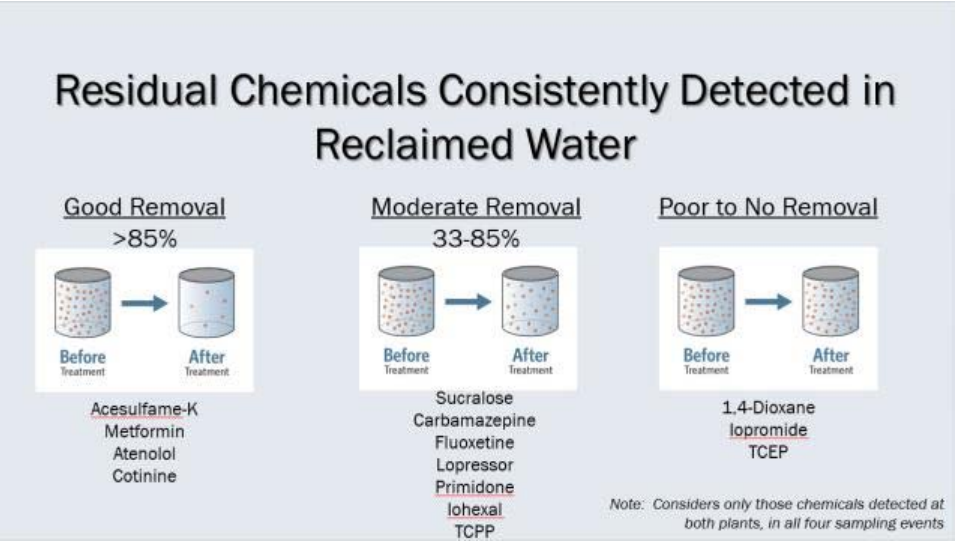


LOTT's treatment processes were highly effective at removing common chemicals such as acetaminophen, ibuprofen, triclosan, and caffeine to levels below detection. Some residual chemicals, however, were consistently detected in reclaimed water in all four sampling events at both of LOTT's facilities (**Figure 3)**. Of these 14 chemicals, those that were detected at the highest concentrations are:

- Artificial sweeteners sucralose and acesulfame-K (with concentrations up to approximately 68,000 and 13,000 ng/L, respectively).
- X-ray contrast agent iohexal (with concentrations up to 14,000 ng/L).
- Anti-diabetic medication Metformin (with concentrations up to 2,600 ng/L).
- Solvent 1, 4-dioxane (with concentrations up to 730 ng/L).

While these chemicals are the most persistent through LOTT's treatment processes, it is important to note that the concentrations in reclaimed water were often significantly less than those in the influent wastewater.

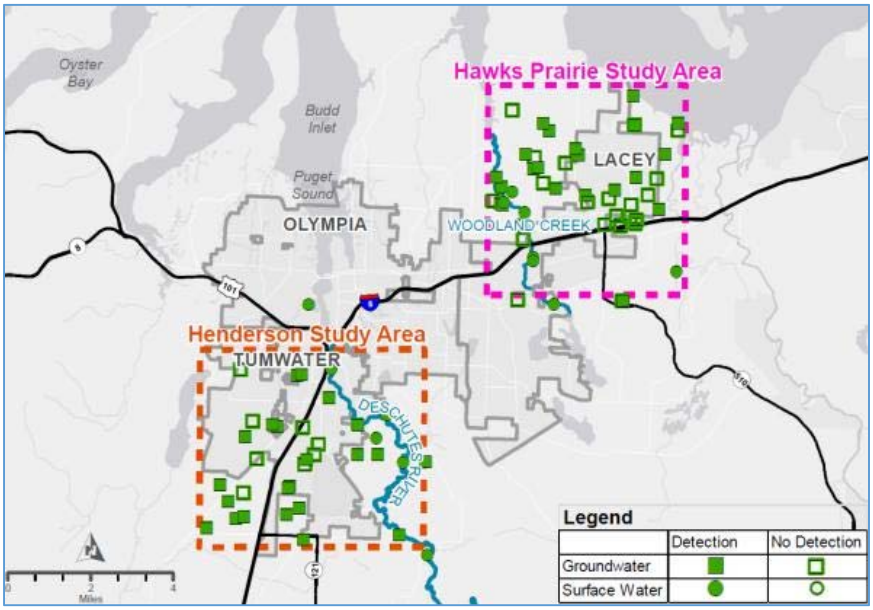
Figure 3. Treatment Effectiveness of Residual Chemicals Consistently Detected in Reclaimed Water



Residual Chemicals – Groundwater and Surface Water

Residual chemicals were detected in both groundwater and surface water throughout the two study areas, at lower frequencies and lower concentrations when compared with the residual chemicals observed in reclaimed water. Potential sources of residual chemicals present in the environment include septic systems, stormwater runoff, and reclaimed water (where it is utilized). **Figure 4** identifies locations of residual chemical detections in the environment.

Figure 4. Residual Chemical Detections in Groundwater and Surface Water

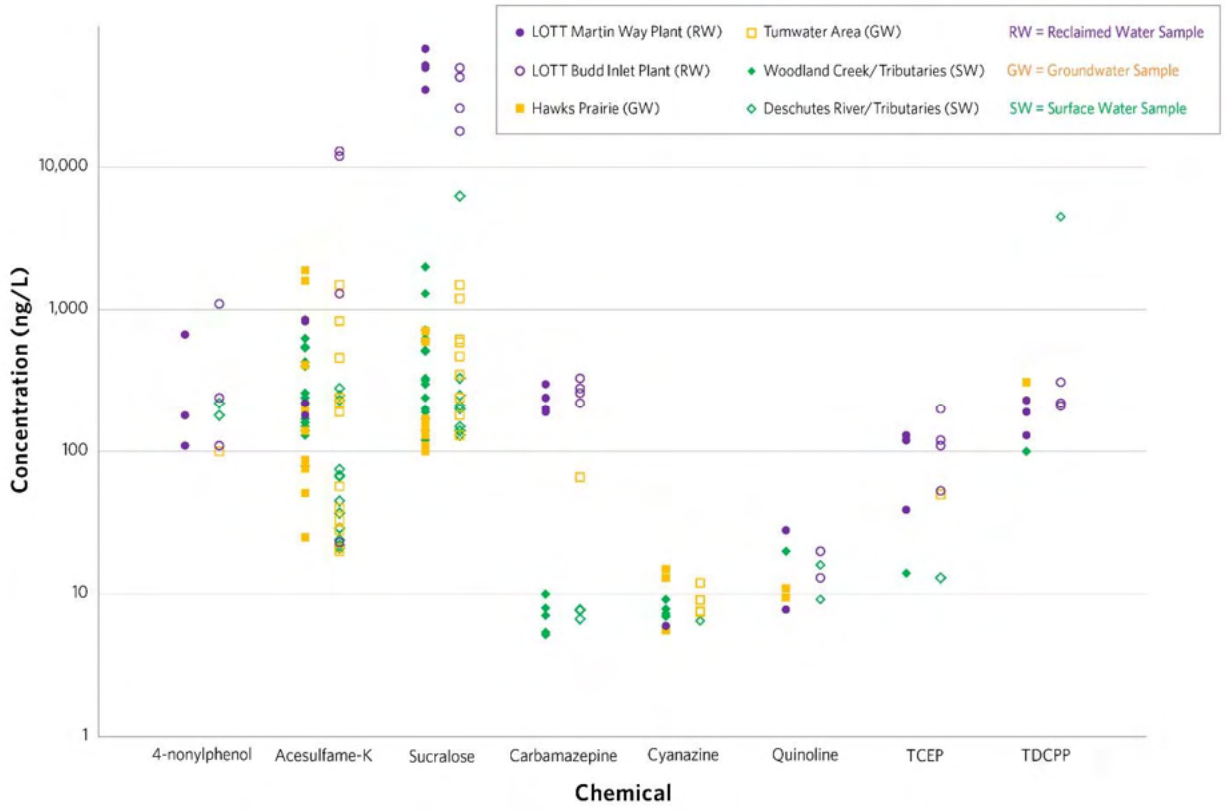


The residual chemicals most frequently detected in groundwater and surface water were the sweeteners acesulfame-K and sucralose. In groundwater these were detected 30 and 21 times, respectively, at concentrations up to 1,900 and 1,500 ng/L, respectively. Similarly, in surface water, these sweeteners were detected 30 and 26 times, at concentrations up to 630 and 6,300 ng/L, respectively. Other residual chemicals were found sporadically at low levels.

Residual Chemicals – Comparison across Waters

Eight residual chemicals were detected at least once in all three types of water: reclaimed water, groundwater, and surface water. **Figure 5** depicts the ranges of concentrations observed for these chemicals.

Figure 5. Concentrations of Residual Chemicals Detected in Reclaimed Water, Groundwater, and Surface Water



Observations regarding the classes of chemicals represented by these residual chemicals are:

- Artificial sweeteners (sucralose and acesulfame-K) – These chemicals are designed to resist being metabolized within the human body, and therefore also persist through the biological wastewater treatment process. Many other studies find these types of chemicals in the environment.
- Flame retardants (including TCEP and TDCPP) – These chemicals are added to common manufactured materials including plastics and textiles to inhibit or suppress the spread of fire. Off-gassing and dust from furniture, building materials, and personal care products can be pathways for inhalation or ingestion, which can then lead to introduction into the sewer system. Laundry wastewater is another potential source of these chemicals into the sewer system.

- Anti-seizure mediations (such as carbamazepine) – This type of pharmaceutical is often cited in other studies because of its persistence through wastewater treatment processes.
- Pesticides (including cyanazine and quinolone, which can also be used in the manufacture of dyes or other industrial products) – There are multiple pathways by which pesticides enter the environment, including stormwater runoff and wastewater.
- Surfactants (such as 4-nonylphenol) – These types of chemicals are used in the manufacture of a wide range of products, such as detergents, lubricating oil additives, and some plastic food packaging.

Comparison to Other Studies

The results of this water quality characterization were compared with those of similar studies conducted in the United States and other countries. The concentrations of residual chemicals in LOTT's reclaimed water are similar to those reported in treated effluent elsewhere. In many cases, the observed concentrations in LOTT's reclaimed water are on the low end of the ranges reported in the literature. Comparison of the study's groundwater and surface water data also yielded results similar to studies conducted in various parts of the country and around the world. Those studies showed detections of pharmaceuticals, antibiotics, pesticides/herbicides, flame retardants, and artificial sweeteners. Some chemicals, such as carbamazepine and cyanazine, were observed at concentrations similar to results in this study. Other chemicals, such as acesulfame-K, have been observed at higher concentrations in groundwater and surface water in other studies as compared to the concentrations found in this study.

Conclusions

Task 1 of LOTT's Reclaimed Water Infiltration Study provides a comprehensive characterization of the quality of LOTT's influent wastewater, treated wastewater, and Class A Reclaimed Water, as well as the water quality in local area groundwater and surface water. Of the 127 total residual chemicals analyzed, about 40% were detected in influent wastewater, and of those, about 40% were removed during treatment to non-detect levels. Only 14 were consistently observed in reclaimed water in all sampling events at both facilities, and of those, removal efficiency varied from good (>85%) to poor (<33%).

Residual chemicals were detected in groundwater and surface waters at concentrations lower than those observed in reclaimed water, and they were detected both in areas where groundwater infiltration of reclaimed water is occurring and where it is not. Results of this study are comparable to those reported in similar studies conducted elsewhere in the country and the world.

Results from this water quality characterization (Task 1) provide a solid foundation for the remainder of the study tasks. These data provide focus for future study analyses, including the human health and ecological risk assessment (Task 3). They also inform the evaluation of alternative treatment processes and related cost/benefit analysis (Task 4). Both Task 3 and 4 are planned to be completed in 2018.

References:

Groundwater Quality Characterization (Task 1.1) LOTT Clean Water Alliance Reclaimed Water Infiltration Study Technical Memorandum February 7, 2017. http://lottcleanwater.org/wp-content/uploads/2015/01/GW-Characterization-Tech-Memo.pdf

Surface Water Quality Characterization (Task 1.2) LOTT Clean Water Alliance Reclaimed Water Infiltration Study Technical Memorandum February 7, 2017. http://lottcleanwater.org/wp-content/uploads/2015/01/SW-Characterization-Tech-Memo.pdf

Wastewater and Reclaimed Water Quality Characterization (Task 1.3) LOTT Clean Water Alliance Reclaimed Water Infiltration Study Technical Memorandum February 7, 2017. http://lottcleanwater.org/wp-content/uploads/2015/01/RW-Characterization-Tech-Memo.pdf