WATER RECLAMATION IN THURSTON COUNTY:
A REVIEW OF LOTT'S PLANNED CLASS A WATER EXPANSION

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Kathryn Ann Smith

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by

Kathryn Ann Smith

has been approved for

The Evergreen State College

by

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Edward Whitesell, PhD
Member of the Faculty

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Date

ABSTRACT

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Kathryn Ann Smith

The Lacey, Olympia, Tumwater and Thurston County (Washington State) Alliance (LOTT) plans expansion of its reclaimed water service to the Tumwater Valley Golf Course and eventually to other areas of the county. Non-potable use of reclaimed water is a way to mitigate the impacts of reduced snow pack in a warmer world and protect valuable riparian habitat. Safety and environmental concerns exist with regard to reclaimed water expansion including microbial organisms, inorganic nutrient, organic compounds and pharmaceuticals/personal care products. A variety of water reclamation facilities exist throughout the U.S. and in other areas of the world and those facilities manage to produce reclaimed water that is below the level of concern for contaminants. By reviewing treatment methods and efficiencies in other parts of the U.S. and comparing those methods and efficiencies with LOTT, it is possible to evaluate how LOTT's operations measure up to those facilities. LOTT operates a state-of-the-art facility that produces a high quality, safe product and its planned expansion will help preserve precious water resources in the South Sound region of Washington.

Table of Contents

Chapter 1 Introduction 1

Chapter 2 Background 8

Chapter 3 Case Study Reviews 24

Chapter 4 LOTT Plant Operations 41

Chapter 5 Comparative Analysis 52

Chapter 6 Conclusion 60

References 63

LIST OF FIGURES

Figure 1: Budd Inlet Plant and the Capitol Campus 4

Figure 2: Deschutes Parkway Reclaimed Water Line 6

Figure 3: Origin and Fate of PPCPs in the Environment 23

Figure 4: Budd Inlet Discharge 43

Figure 5: Wastewater Treatment Plant Flow...46

Figure 6: Bardenpho© Four Stage Biological Treatment.....................49

LIST OF TABLES

Table 1: Water reuse categories and typical applications 3

Table 2: Estimate of Percent Removal of Selected Microbial Pathogens Using Conventional Treatment Processes..............16

Table 3 Orange County Injection Requirements 32

Table 4: Hawks Prairie Reclaimed Water Satellite Ground Water Quality Criteria ………………………………..............................35

Table 5 Yelm Groundwater Monitoring Comparison (Averages)...36

Table 6: PPCPs in Wells Adjacent to Sequim WWTP Water-Reuse Project ……………………………………………..........................38

Table 7: NPDES Permit Summary, Budd Inlet Treatment Plant, Effective October 1, 2005...44

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1. INTRODUCTION

Water is a resource necessary for life on our planet. In Western Washington, residents are very fortunate that water is an abundant commodity, continually renewed by rainfall and snowmelt. Concerns are mounting regarding the potential effects of global climate change and how that phenomenon could affect our sources of water (WA DOE 2005). Models indicate that the Pacific Northwest will receive less winter precipitation as snow and more rain in the coming decades due to climate change. As a result of warming trends, western Washington will have less snow accumulation accompanied by higher winter stream flows, followed by earlier spring snowmelt and earlier peak stream flows. As a result of earlier melting of the snow pack, the summer stream flows will be reduced (CIG 2009). While water sources are expected to drop, the population is expected to increase (WA DOE 2005).

If summer stream flows do decrease as modeling suggests, riparian habitats could be threatened. Maintaining adequate stream flows for fish runs is also a concern in western Washington. As riparian habitats may be threatened by reduced flow, it would be irresponsible to continue pulling water from rivers and streams (Cupps 2005).

With an expected increase in demand and a potential decrease in supply, it is important to find a new source of water. Many municipalities in Washington State are turning to reclaimed water to supply that need. The Washington State Departments of Health (DOH) and Ecology (DOE) define reclaimed water as:

> …effluent derived in any part from sewage from a wastewater treatment system that has been adequately and reliably treated, so that as a result of that treatment, it is suitable for a beneficial use or a controlled use that would not otherwise occur and is no longer considered wastewater (WA DOH and DOE 1997, 10).

Water supply is especially important for those who live in urban areas. City dwellers (in most cases) cannot procure water for their needs by themselves. The increase in urbanization coupled with higher standards of living make more and more demands on urban water supplies and those increased demands could lead to shortages (Okun 2000). Reclaimed water can satisfy urban requirements for secondary, i.e., sub-potable, water (Mills and Asano 1998). Examples of secondary water uses include toilet flushing, recreational lakes, and water hazards on golf courses. Water that is introduced into the environment should be of sufficient quality to support the native flora and fauna in the area. Water too rich in nutrients could lead to algae blooms and subsequent eutrophication of the area (Asano and Levine 1998). Table 1 (below) identifies a variety of beneficial applications for reclaimed water.

Table 1. Water reuse categories and typical applications

Category	Typical application
Agricultural irrigation	- Crop irrigation - Commercial nurseries
Landscape irrigation	- Parks - Schoolyards - Freeway medians - Golf courses - Cemeteries - Greenbelts - Residential
Industrial recycling and reuse	- Cooling water - Boiler feed - Process water - Heavy construction
Groundwater recharge	- Groundwater replenishment - Saltwater intrusion control - Land subsidence control
Recreational/environmental uses	- Lakes and ponds - Marsh enhancement - Streamflow augmentation - Fisheries - Snowmaking
Non-potable urban uses	- Fire protection - Air conditioning - Toilet flushing
Potable reuse	- Blending in water supply reservoirs - Blending in groundwater - Direct pipe-to-pipe water supply

Asano 2006

We no longer have the luxury to use water just once. Water reclamation is environmentally responsible because it preserves the health of waterways, wetlands and their associated habitats, and it reduces the level of nutrients and other pollutants entering waterways and sensitive marine environments by reducing effluent discharges (Asano 2006).

The urban areas of Thurston County are served by the Lacey, Olympia, Tumwater and Thurston County Alliance (LOTT) for wastewater treatment and disposal. Figure 1 (below) shows the location of the Budd Inlet Wastewater Treatment plant. LOTT performs primary and secondary treatment on all wastewater to remove settleable and nonsettleable solids, nutrients and biological organisms. A portion of that treated water receives tertiary treatment to meet reclaimed water standards (LOTT 2006).

Figure 1: Budd Inlet Plant and the Capitol Campus

(LOTT 2009a)

Reclaimed water might contain contaminants that eluded the treatment process, such as microbes, organic compounds, and inorganic compounds (Erickson 2004). Pharmaceuticals and personal care products (PPCPs), while not new compounds (some have been known for over 30 years to be present in the environment), are receiving increased attention, as more hazards associated with their presence are identified (Daughton 2001). Each type of contaminant and its associated hazard will be discussed in chapter 2.

Washington State's General Administration (GA) Department converted much of the Capitol campus irrigation to reclaimed water in 2007 (WA GA 2008). According to the GA's 2008 Sustainability Report, in 2007 over 6,000,000 gallons of reclaimed water irrigated Heritage Park, Marathon Park and along Deschutes Parkway (2008). Figure 1 (page 4) illustrates the location of the Capitol campus that is using reclaimed water. LOTT plans continued use of reclaimed water with expansion to the Tumwater Valley Golf Course, see Figure 2 (page 6) for an illustration. This expansion is expected in 2010 and would supply approximately 500,000 gallons of water per day to the golf course, doubling the amount of reclaimed water used in the South Sound (Dodge 2008).

Reclaimed water appears to be the answer to many problems associated with our growing population and potential reduction in water availability. But is it really? Reclaimed water will replace 1,000,000 gallons per day (MGD) of potable water by 2010 but is it really safe to expand its use?

Figure 2: Deschutes Parkway Reclaimed Water Line

(LOTT 2009a)

This thesis research project set out to answer the above question. The principal finding of this research is that, yes, it is safe to expand the use of reclaimed water in the greater Olympia area. Furthermore, this thesis contends that such use is the most responsible choice, given potential water shortages in the future. It is not however, the answer to all problems associated with water use in Thurston County. Besides adding a new source of water to the area, citizens must also practice conservation.

This thesis will review the expected benefits and potential problems associated with reclaimed water and compare LOTT's treatment processes to other facilities, with particular attention to safety and efficiency. This comparison will be accomplished by a review of authoritative sources, to determine if LOTT meets or exceeds the technology employed by other municipalities, as demonstrated by LOTT's ultimate authority – its permit.

Chapter 2 provides background information regarding the benefits municipalities may achieve with reclaimed water and potential environmental and health hazards associated with reclaimed water use. Chapter 3 consists of a review of several case studies related to reclaimed water use in municipalities in other areas of the U.S. and the world. Chapter 4 is dedicated to LOTT plant operations and efficiency, including the treatment methods used at the LOTT facilities and discussion of its permit. In chapter 5, I will compare LOTT operations with those case study operations discussed in chapter 3, to determine how LOTT compares with other facilities. I will conclude this thesis in chapter 6.

2. BACKGROUND

History and Use of Reclaimed Water

Humans have reused water – either intentionally or unintentionally – for millennia. There are indications communities reused wastewater for irrigation as long as 5,000 years ago (Asano and Levine 1998). Discharge of wastewaters into rivers and streams in London led to an inadvertent use of wastewater as potable water, leading to the spread of waterborne diseases such as Asiatic cholera and typhoid in the 1840s and 1850s (Okun 2000). The link between wastewater and the spread of disease in the 1850s and '60s led to more careful planning in the discharge and use of protected reservoirs for drinking water (Asano and Levine 1998).

Intentional reuse of wastewater in the United States started in the early 20th century. The community of Bakersfield, California, began using wastewater for irrigation in 1912. California promulgated wastewater regulations in 1918. Throughout the first half of the 20th century wastewater was used around the southwestern U.S. for a variety of agricultural and industrial purposes (Asano and Levine 1998).

Water reclamation (as opposed to the term wastewater reuse which indicates no treatment) came to the forefront in the 1970s as a means to supplement existing water sources and replace the use of potable water in certain applications. Technological advances in treatment techniques made water reclamation possible for almost any quality needed (Asano and Levine 1998). In 1990, estimated usage of reclaimed water in the United States was 1.5 billion gallons per day. California used 240 MGD in 1987 – mostly for agricultural applications (63 percent) with approximately 23 percent for urban applications (Crook 1998).

As reclaimed water use is expanded in urban areas and in those areas where potable and sub-potable water may both be pumped in, water providers must install dual distribution systems to keep the sub-potable water from the potable water supply (Crook 1998). James Crook conducted a study for DOH regarding the public health risks associated with reclaimed water. DOH summarized Dr. Crook's findings in its 2007 Reclaimed Water Use Legislative Report. Dr. Crook indicated that the only documented disease outbreak in the United States from reclaimed water happened in Arizona in 1979. Crook stated the outbreak was caused by a cross-connection between the reclaimed water used for watering trees and shrubs in a campground and the potable supply for that campground. Crook emphasized that this incident happed prior to Arizona adopting reclaimed water regulations (WA DOH 2007).

In 2004, the U.S. Environmental Protection Agency (EPA) developed guidelines for water reuse but it is only an advisory document (US EPA 2004). Actual regulation takes place at the state level. In Washington, reclaimed water requirements are published by both DOE and DOH, where the former issues permits for water usage and the latter investigates health concerns (WA DOH 2007). LOTT produces water that meets Class A reclaimed water, which is defined as:

> water that, at a minimum, is at all times an oxidized, coagulated, filtered, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the number of total coliform organisms does not exceed 23 per 100 milliliters in any sample (WA DOH 1997, page 7).

LOTT distributes its reclaimed water to the Capitol campus for landscape applications and other secondary processes (e.g., boat washing and cleaning). It also utilizes a created treatment wetland (CTW) in the Hawks Prairie area to recharge the local aquifer (LOTT 2009a). Aquifer recharge is a common use of reclaimed water and will be discussed in chapters 3 and 4.

The Reclaimed Water Act of 1992, Chapter 90.46 RCW, amended several times; mandates that reclaimed water be adequately and reliably treated prior to distribution (RCW 1992).

LOTT's requirements for distribution are directed under its National Pollutant Discharge Elimination System (NPDES) Permit WA0037061 (WA DOE 2005).

Potential Benefits of Reclaimed Water Use

Communities that choose water reclamation can reap tremendous benefits from their investment. The first and most important benefit is water conservation. When a community is facing a water shortage, the first step involves using less water. Incentives for community conservation include "water saving devices" such as low-flow showerheads and toilets. Also effective is incentive pricing to decrease water use (Okun 2000).

Community conservation works well on an individual level and helps to enforce the necessity of conservation. A community may see lower per-capita water use, but if the community continues to grow (as most urban areas do) that conservation will not meet all needs. Urban areas must find more sources of water to conserve their potable sources. Reclaimed water can meet this need (Okun 2000).

Another benefit of reclaimed water is the dependable nature and local control of the source of water (Hermanowicz, Diaz and Coe 2001). Many urban areas are dependent on surface waters such as streams and rivers. By diverting water from streams and rivers, urban communities could cause severe environmental impacts to the ecological communities in and around those surface waters. Water reclamation can reduce some of those ecological impacts (Erickson 2004).

Some urban areas (like urban Thurston County) are fortunate to have a high quality source of groundwater for use as drinking water. The concern involves withdrawing that groundwater faster than the recharge rate of the aquifers. Reclaimed water eases the burden on groundwater supplies without resorting to importing water from other areas (Okun 2000).

Water reclamation also reduces the amount of wastewater effluent discharged into receiving waters. The LOTT Budd Inlet Wastewater Treatment Plant (WWTP) receives approximately 13.5 MGD of wastewater (WA GA 2007). LOTT currently has a maximum reclamation capacity of 1.5 MGD. That is 1.5 million gallons of wastewater effluent that is not discharged into Budd Inlet (WA DOE 2005). LOTT is constructing a satellite plant at Hawks Prairie (in Lacey, adjacent to Olympia) that will eventually treat 5 MGD to Class A standards. Additional plants are planned in Tumwater and Chambers Prairie (also in Lacey) to further reduce wastewater effluent (WA DOE 2005). The increased treatment of the Class A water reduces the detrimental impacts of wastewater effluent discharged to the environment.

Another positive result of water reclamation is a potential reduction in costs for wastewater treatment. If municipal treatment plants are able to provide a marketable product, that revenue should reduce the cost of domestic wastewater treatment for LOTT's customers (Erickson 2004).

Finally, water reclamation could lead to increased or retained economic activity in those communities. A reliable, affordable water supply may make a community more attractive to new and existing businesses (Erickson 2004).

Potential Hazards in Reclaimed Water

Reclaimed water is not without problems or hazards. As stated earlier, a problem with a cross connection at an Arizona campground led to dozens of campers becoming sick from a water-borne disease. But, as also stated earlier, this is the only documented illness in the U.S. that has been directly linked to reclaimed water.

Contaminants that may be present in reclaimed water are microbes, organic compounds and inorganic compounds (Erickson 2004).

Microorganisms

Microbial organisms that exist in wastewater are bacteria, viruses and parasites. As warm-blooded organisms, humans normally have bacteria present in their gastrointestinal tract and shed approximately 1 trillion bacteria per gram of fecal matter. Most bacteria found in human fecal matter is non-pathogenic and is adapted to conditions of the gastrointestinal tract. Therefore, they cannot compete with other bacteria outside the body. However, an individual infected with a gastrointestinal pathogen can shed up to 1 billion bacterial organisms per gram of fecal material. These bacteria can be spread to others through direct contact or ingestion of contaminated water. Examples of pathogenic bacteria are: *Salmonella*, *Shigella*, *E. coli*, and *Legionella* (Yates and Gerba 1998).

Viruses are not normally found in the intestinal tract of healthy individuals. A person must be infected with a virus to have it present in his or her fecal matter. An individual infected with rotavirus (the most common cause of diarrhea in young children [CDC 2008]) can shed as many as 1 trillion particles per gram of feces for up to two months. Other viruses can be shed for even longer (Yates and Gerba 1998).

Parasites are also only present in affected individuals and are classified in two groups – protozoa and helminths . The protozoa are single celled organisms. The helminths include a variety of multi-celled worms. An infected individual can shed 1 – 10 million *Giardia* (protozoa) per gram of feces for up to 6 months (Yates and Gerba 1998).

Most of these pathogens are removed through the standard treatment processes at WWTPs during both the activated sludge process (where enhanced oxygenation of wastewater leads to pathogenic organisms being out-competed by non-pathogenic organisms) and during disinfection. But, most wastewater effluent is not pathogen free when discharged to receiving waters. This means additional treatment techniques are required prior to classification as reclaimed water. The more intimate the human contact with the water, the more stringent the treatment processes required (Cooper and Olivieri 1998). Table 2, page 16, identifies estimated efficiency of conventional wastewater treatment plants for selected microorganisms.

The reduction of these selected microorganisms through secondary treatment processes is very impressive – ranging from

Table 2: *Estimate of Percent Removal of Selected Microbial Pathogens Using Conventional Treatment Processes*

Microbial Agent	% Removal with Primary Treatment	% Removal with Secondary Treatment
Salmonella	50	99
Enteric virus	70	99
Giardia cysts	50	75
Helminth ova	90	99.99

(Cooper and Olivieri 1998)

75 percent to 99.99 percent removal. But, as stated earlier, *Giardia* may be present in up to 10 million organisms per gram of feces. This leaves millions of *Giardia* that may still be present in wastewater effluent. The massive numbers of microorganisms present in the water leave millions that may still be present even with 99 percent removal during treatment (Cooper and Olivieri 1998).

The answer to more efficient removal of pathogens from wastewater effluent lies in tertiary or advanced treatment. Reclaimed water in Washington must undergo tertiary treatment to ensure the water meets Class A standards. Particulars of tertiary treatment will be discussed in chapters 3 and 4.

Organics

The next contaminant group of concern is organic chemicals. A variety of volatile compounds (including methylene chloride, chloroform, dichloroethene, tetrachloroethylene, toluene, ethylbenzene, acetone, and xylene) and semi-volatile organic compounds (including phenols and phthalates) are present in very low levels in wastewater effluent. These compounds make their way into the domestic waste stream from the disposal of a variety of chemicals by residential and commercial users. The extreme low levels of these types of contaminants and the fact that the water is non-potable make them a point of non-concern for health purposes (Asano and Levine 1998).

A recent study conducted in China suggests that wastewater may be a source of persistent organic compounds such as polychlorinated biphenyls (PCB) and polybrominated diphenyl ethers (PBDE), and that the WWTP may enhance the bioaccumulation of these persistent chemicals in aquatic life. The researchers admitted their research might have been confounded by environmental impacts such as temperature fluctuations. (Wang et al. 2007)

Another recent study conducted in Spain evaluated the presence of organic compounds found in aquifers supplied by recharge basins. They concluded that organic chemicals could seep through the soil and make their way into the aquifer – potentially causing serious problems if that water is used as a potable source. They also concluded that those chemicals were below the levels considered hazardous to health (Diaz-Cruz and Barcelo 2008).

There are organic compounds that are found in highly treated wastewater in milligram/liter quantities. These compounds are resistant to treatment and cannot be readily decomposed or broken down and are referred to as stable organic compounds. Some organic compounds are classified as trace organic compounds because they have passed through extensive treatment processes. Stable/trace organic compounds are significant in reclaimed water used for groundwater recharge for the following reasons:

1. the identity of each organic compound is not well known;
2. the effects of treatment processes and soil filtration on such compounds is not clear; and
3. the chronic health effects associated with ingestion of low levels of stable organic compounds over time are also poorly understood (Asano 2006).

Inorganics

Inorganic compounds including nutrients, salts, and heavy metals are the next-listed contaminant of concern for reclaimed water (Erickson 2004). Nutrients are of particular concern, as they can lead to increased algae growth and eventually to eutrophication in receiving waters. Advanced treatment techniques may use microorganisms to reduce nutrients prior to beginning the tertiary process. Heavy metals are responsive to initial treatment techniques and do not pass through the treatment process. Because metals settle out during treatment, they do not pose a significant health risk in reclaimed water (DOH 2007).

The main concern is not whether WWTPs can treat effluent to a point where that water is safe; rather can the WWTPs treat the water *consistently* to safe levels? Consistency is measured through meeting the maximum contaminant limit (MCL) for regulated inorganic contaminants found in the WWTP's permit for water discharge (Asano and Levine 1998). WWTPs are required to show consistency through frequent testing of the effluent (Nathanson 2008). Nitrates are especially problematic as they could lead to methemoglobinemia (blue baby syndrome)(Asano and Levine 1998). There are treatment methods that significantly reduce the presence of nitrates in effluent and the methods used by LOTT will be discussed in chapter 4.

Pharmaceuticals and Personal Care Products

A relatively new category of concern in reclaimed water is pharmaceuticals and personal care products (PPCP). PPCPs may pass through the treatment processes and make their way into receiving waters or groundwater, posing a potential health risk (Chefetz, Mualem, and Ben-Ari 2008). (See Figure 3, page 23 for an illustration of how PPCPs enter the environment.) The US EPA (2009) identifies PPCPs as problematic in wastewater (and subsequently in reclaimed water) because:

- human and animal use of PPCPs can lead to large quantities of PPCPs entering the environment;
- current technology does not provide for PPCP removal in WWTP;
- as the concentrations are so low, it is difficult to determine the effect of PPCPs on aquatic environments and humans; and
- the numbers are growing. As of 2007, more than 100 individual PPCPs have been found in both environmental sampling and in drinking water (US EPA 2009).

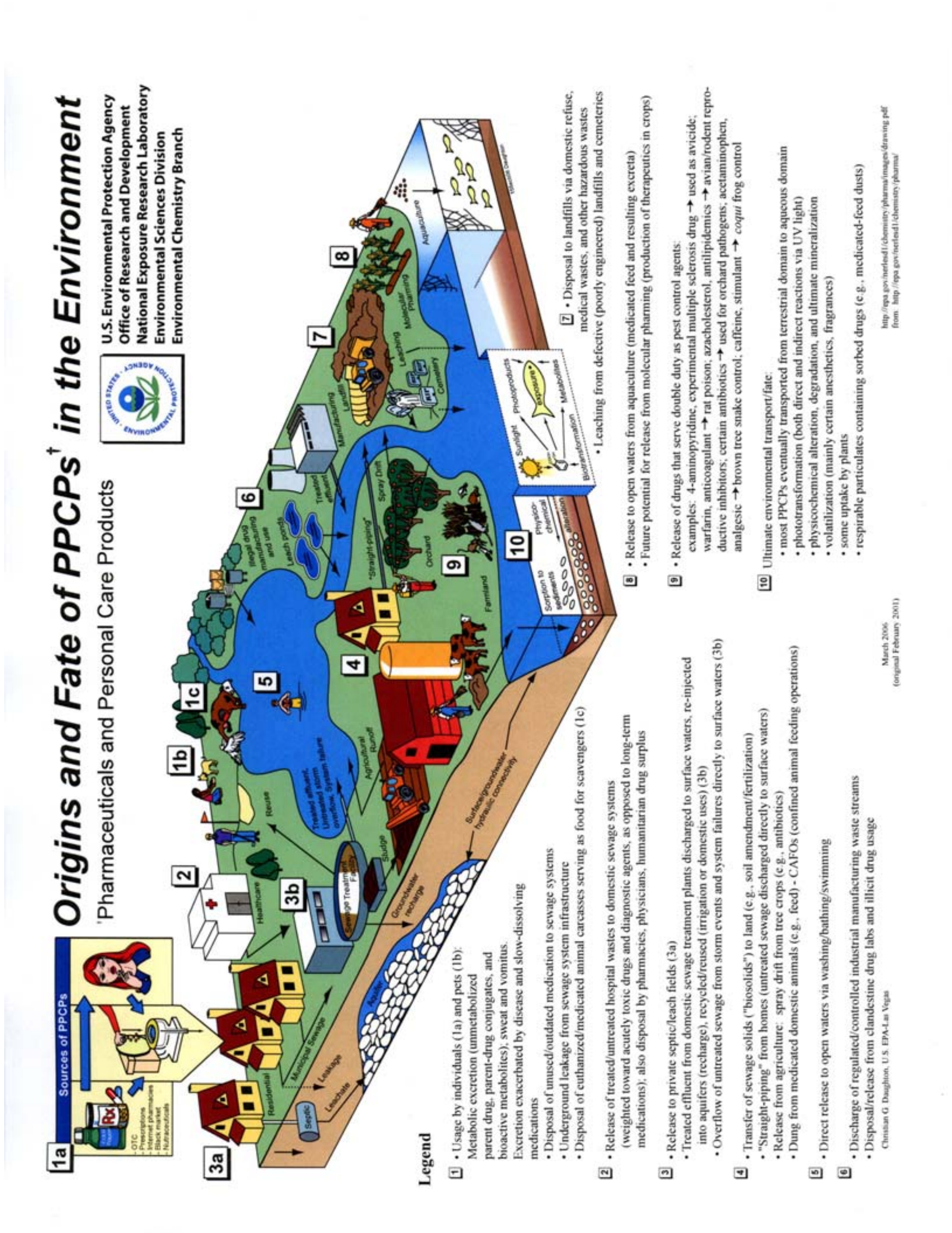
A study of drinking water heavily influenced by wastewater effluent in San Diego found phthalate esters, sunscreens, clofibrate, clofribric acid, ibuprofen, triclosan, and DEET present in the raw water (Lorraine and Pettigrove 2006). Studies indicate that exposure to even trace amounts of pharmaceuticals can lead to long-term health risks. Also, many of these PPCPs are classified as endocrine disruptors that affect natural hormone development and can impact amphibians, fish and other wildlife even in the parts per trillion (Daughton 1999).

The concern about PPCPs is growing because sampling has detected so many at low levels (µg/L and ng/L) but little is known of their potential for accumulation causing adverse human or ecological effects (Johnson, Carey, and Golding 2004). Also, any decomposition or degradation of their compounds is offset by their constant reintroduction to the environment (Daughton 2001). Most troublesome about the PPCPs is how difficult they are to detect in effluent. There are so many compounds that analysis becomes prohibitively expensive and time-consuming. Research is ongoing to find an answer to this particular problem (Levine and Asano 2004).

Reclaimed water provides a new source of water that could replace the use of potable water in many areas. As a result of using reclaimed water, less water is pumped from rivers and streams saving riparian habitats. Also, utilizing reclaimed water leads to less groundwater pumping saving that precious resource for potable needs.

Potential problems that may result from reclaimed water use include: microbes, organic compounds and inorganic compounds. Treatment methods have demonstrated consistent, safe treatment of reclaimed water. Tertiary treatment methods employed in the reclaimed water process are more efficient in removal of pathogenic microorganisms. While organic and inorganic contaminants are found in reclaimed water, the levels reported are so low they fall below the level of concern for human health hazards. PPCPs are another, relatively new contaminant of concern. At this time, the effects of PPCPs in the environment are relatively unknown but research is continuing. Although not all concerns can be answered completely at this time, Washington State Departments of Health and Ecology and the U.S. Environmental Protection Agency are proactively researching these issues.

Figure 3. Origin and Fate of PPCPs in the Environment



(US EPA 2009)

3. CASE STUDY REVIEWS

A variety of case studies exist documenting research conducted on water reclamation processes. This paper will review several cases from different municipalities in California, a case in St. Petersburg, FL, cases from the Catalonia region of Spain and then review two cases in Western Washington State for comparison of treatment technologies with the treatment operations at the LOTT facilities. The case studies reflect a variety of methods for water reclamation and provide a framework by which LOTT's operations will be compared.

LA County

Los Angeles (LA) County provides wastewater treatment to over 5 million residents in 79 communities outside of the City of Los Angeles. The Sanitation Districts of Los Angeles County operate 10 water reclamation plants that have a capacity to treat over 220 MGD (Hartling and Nellor 1998).

Water reclamation in LA County is spurred by the climate in the LA area – the county receives an annual average of only 15 inches of rain per year, and there are no major rivers within 100 miles (Hartling and Nellor 1998).

Water was diverted, starting in 1913, from the Owens River in central, eastern California, to supply growing communities in LA County. Owens Lake was situated at the terminus of the Owens River but so much water has been diverted from the Owens River that Owens Lake is currently a dry lake and the thriving ecosystem it once supported is gone. Also, dust originating in the dry lake contributes to poor air quality in the region (Reheis 1997). In 1941 – 1990 water was also diverted from the Mono Lake Basin resulting in the loss of half the volume of Mono Lake (Mono Lake Committee 2009). As a result of significant water loss in Mono Lake and the desiccation of Owens Lake, pumping operations from both of these major sources of water were permanently stopped by 1994 (Hartling and Nellor 1998).

In the 1990s, the county also anticipated a 50 percent reduction in its water supply from the Colorado River, as more water was being diverted in Arizona (Hartling and Nellor 1998). In 1997, Arizona began using its full water allotment from the Colorado River, removing between 300,000 and 1,000,000 acre-feet of water previously available for use in California (Gelt 1997). Furthermore, Metropolitan LA is in competition with regional agricultural users for water supply (Hartling and Nellor 1998).

All the LA County plants discussed in the case study use the same type of treatment process. Water is pumped through primary and secondary processes. The treated effluent is dosed with a coagulant and chlorine, and is then filtered. The filtered water is again chlorinated and stored in a chlorine contact tank for at least 90 minutes while continuous monitoring takes place to ensure proper dosage. The three stages of treatment remove more than 99 percent of suspended solids. Dissolved salts are unchanged in this process. The water is now considered fully treated and ready for reuse. Any water discharge to a river or stream must be dechlorinated to protect flora and fauna (Hartling and Nellor 1998).

According to Hartling and Nellor's study, there are no adverse health effects associated with using properly treated reclaimed water (1998). The reclaimed water produced by the Sanitation District meets EPA and California drinking water standards for heavy metals, pesticides, trace organics, and radioactivity. The tertiary effluent produced contains less than 1 coliform bacterium per 100 mL. Virus sampling was conducted on 981 samples of tertiary effluent from 1979 – 1998 and only one sample tested positive for virus (Hartling and Nellor 1998).

A problem with the tertiary effluent is the lack of nutrient removal. Nutrients are not removed by standard treatment and the tertiary process does not include nutrient removal either. This provides a benefit for those using water for irrigation, as this would supplement or even replace fertilizers, but it leads to algae growth in the storage ponds; due to the problem of algae, storage ponds were discontinued. A more serious problem is the presence of nitrogen in water used for groundwater recharge – that nitrogen can be nitrified into nitrates by soil bacteria. Nitrates can lead to methemoglobinemia (blue baby syndrome). Regular sampling of the aquifers has shown only slight changes in nitrate levels (Hartling and Nellor 1998).

Irvine (CA) Ranch

An early entry into use of reclaimed water is the Irvine (CA) Ranch Water District (IRWD). IRWD began supplying reclaimed water to agricultural customers in 1967. By 1998, IRWD distributed reclaimed water to landscape irrigation, recreational uses and toilet flushing. It also received permits in 1991 to become the first water district to provide reclaimed water in the interior of office buildings, cutting potable water demands by as much as 75 percent. Irvine utilizes reclaimed water to supply toilets, urinals, and landscape requirements in the city. In Irvine, all new developments must be built with dual distribution systems to provide both reclaimed and potable water (Young et al. 1998).

IRWD operates under an NPDES permit that requires the highest quality water for use in parks, playgrounds, school irrigation and water contact recreation. The water must have an average of less than 2.2 coliforms per 100 mL over a one-week period. The IRWD reclaimed water meets all California reuse requirements.(Young et al. 1998).

The method used for tertiary treatment is the same as that of LA County. Like the LA County treatment plants, IRWD did not originally treat for nutrients in its tertiary effluent. This led to several quality problems in its reclaimed water reservoirs including increased turbidity levels and algae growth. Also, dissolved sulfide levels are elevated, causing odor issues (Young et al. 1998).

IRWD currently utilizes a biological nitrification/denitrification process in its tertiary treatment process that removes those nutrients (IRWD 2009). Utilizing a nutrient removal system reduces the amount of eutrophication in the receiving waters.

St. Petersburg, Florida

St. Petersberg is a city of 250,000 permanent residents and thousands of transient residents, and it is surrounded by saltwater on three sides. The unique hydrology of the area led to significant water shortages starting in the 1920s, after the only freshwater lake in the area was over-pumped. An increasing number of wells supplied the city with water. In the 1970s, the wells began to show signs of overstress and the city was facing potential water shortages with very few options for new development (Johnson and Parnell 1998).

In 1972, St. Petersburg developed a plan to reclaim wastewater for irrigation of golf courses and for a deep injection well system. The plan was very ambitious, with a goal to reach zero discharge to surface water from the city's WWTPs. The city's goal was achieved in 1989. The deep well disposal is only used when storage capacity is full at the appropriate facilities (Johnson and Parnell 1998). Storage capacity is only reached during rainy months as the water district fully utilizes all water for irrigation during dry months (Pinellas County 2009). Deep well disposal includes injecting the reclaimed water into a confined saltwater aquifer, where the water ends up in the Gulf of Mexico (Johnson and Parnell 1998).

St. Petersburg's WWTPs are defined as "advanced secondary" rather than tertiary treatment plants. The treated effluent undergoes filtration and chlorination prior to discharge (Johnson and Parnell 1998).

The St. Petersburg City Council commissioned a study that determined "there is no evidence of increased enteric disease in urban areas irrigated with treated reclaimed water…" or from any aerosols from spray irrigation (Johnson and Parnell 1998, page 1055).

Interestingly, the authors identified the presence of nutrients in the effluent as beneficial to the communities. Elevated levels of nitrogen and phosphorus, as well as trace amounts of calcium, magnesium and iron are considered a selling point for the water when used for landscaping.

Orange County, CA

Orange County, California started groundwater recharge using both direct injection and surface spreading of effluent in the 1970s. Agricultural water uses in the county have been replaced with urban needs, leading to over-pumping and consequent intrusion of seawater into the aquifer. Orange County uses over 200 wells to supply 75 percent of the water for its 2 million customers. The rest of its water is imported from the Colorado River and northern California (Mills, Bradford, Rigby and Wehner 1998).

Maximizing the availability of high-quality ground water is a prime goal of the Orange County Water District (OCWD). By effectively managing groundwater resources, OCWD can reduce its dependence on water imports. Its first project was to inject high quality effluent into coastal aquifers, preventing the intrusion of seawater into the aquifer. The second program called for spreading the water for groundwater recharge in the northeastern part of the county. By spreading the water there, OCWD was able to benefit from the natural percolation and recharge capabilities of the site (OCWD 2004).

Since OCWD directly discharges reclaimed water into aquifers, it is required to perform more stringent treatment than would a standard WWTP. The treated effluent is chemically clarified by the addition of lime to the stream, achieving a pH of 11.2, followed by rapid mixing, flocculation and sedimentation. This removes over 99 percent of coliform bacteria, 26 percent of total organic compounds, and significantly reduced levels of the inorganic compounds. Table 3 (page 32) is a summary of the injection water-quality requirements for Orange County (only those parameters found in the DOE’s additional groundwater criteria for Washington are identified) (Mills, Bradford, Rigby, and Wehner 1998).

OCWD conducts extensive testing for microbial, organic and inorganic contaminants. Water quality from the OCWD treatment plants consistently meets or exceeds drinking water standards (Mills, Bradford, Rigby, and Wehner 1998).

The OCWD manages the underground water reserves that supply approximately 500 wells within its district boundaries. In 2006 about 333 million m^3 of this water is pumped for use each year. That quantity continues to grow steadily, and projections indicate the demand may reach as much as 555 million m^3 per year by 2030 (Asano 2006).

Table 3 Orange County Injection Requirements

Additional Ground Water Quality Criteria

Parameter	Concentration
Total Dissolved Solids	500 mg/L
Chloride	120 mg/L
Sulfate	125 mg/L
Copper	1000 μg/L
Lead	50 μg/L
Manganese	50 μg/L
Silver	50 μg/L
Zinc	5000 μg/L
pH	6.5 to 8.5 standard units
Lead	0.3 mg/L

(Mills, Bradford, Rigby, and Wehner 1998, page 1118)

Catalonia

A municipality in the Catalonia Region of northeastern Spain recently began using reclaimed water to rehabilitate wetlands. Besides looking at conventional pollutants (which are highly studied), a recent study focused on the presence of PPCPs in created treatment wetlands (CTWs) (Llorens, Matamoros, Domingo, Bayona, and Garcia 2009).

A small (1 hectare) CTW in an urban environment near the Mediterranean Sea is where researchers tested both the influent and effluent for eight PPCPs. The removal efficiency for these compounds ranged from 35 percent to 98 percent. Two of the compounds had better than 95 percent, three greater than 80 percent, one was 72 percent, and the final two had poor efficiency at 34 percent and 39 percent (Llorens, Matamoros, Domingo, Bayona, and Garcia 2009).

Llorens and his colleagues also observed environmental benefits as the CTW greatly enhanced the biodiversity of the area. They concluded that natural processes may be efficiently used for reclaiming water (Llorens, Matamoros, Domingo, Bayona, and Garcia 2009).

Due to potential drought conditions in the Catalonia region, reclaimed water use is expected to increase sharply. In 2007, a two-year drought forced the region to import water by boat, as reservoir levels fell to 15 percent (a level at which water is rendered non-potable due to sediment). To prevent something like this in the future, the Catalonian government is planning to meet 50 percent of future water demand with reclaimed water, including agricultural irrigation water (Andrews 2008).

Water quality from the Catalan region is of high enough quality that it could be diverted directly into the potable water system. However, the treatment plant operations plant director indicated that Europeans are not psychologically ready for utilizing reclaimed water for drinking water (Andrews 2008).

Yelm, Washington

Water reclamation in the city of Yelm provides interesting insight into the contamination that may be present in groundwater as a result of reclaimed water use. The Washington Department of Ecology (DOE) has strict standards regarding reclaimed water used for groundwater recharge (see Table 4, page 35). The water must meet the Class A standard and must undergo biological nitrogen reduction (Cupps 2005).

Yelm is a rapidly growing city located in Thurston County, Washington. Faced with an increasing population, declining water resources and a need to protect declining salmon runs in the Nisqually River, in 1993 Yelm began planning for ground water recharge with reclaimed water. In 2000, Yelm became the first city in Washington to achieve 100 percent water reclamation (Skillings 2000).

Table 4. Hawks Prairie Reclaimed Water Satellite Ground Water Quality [Discharge] Criteria

Parameter	Concentration
Total Dissolved Solids	500 mg/L
Chloride	250 mg/L
Sulfate	250 mg/L
Copper	1300 µg/L
Lead	15 µg/L
Manganese	50 µg/L
Silver	100 µg/L
Zinc	5000 µg/L
pH	6.5 to 8.5 standard units
Total Iron	0.3 mg/L
Toxics	No toxics in toxic amounts

(WA DOE 2006, page 7)

Yelm has shallow drinking water wells. It currently produces about 250,000 gallons per day of reclaimed water, which is used for irrigation of schools and a city park (including a fish pond followed by a series of CTWs.) Yelm received DOE’s “Environmental Excellence Award” in 2002 for successfully implementing Class A reclaimed water (Cupps 2005).

Along with the standard treatment operations required by the Clean Water Act, Yelm employs nitrogen removal during secondary treatment. The effluent is then sent through filtration, mixing and chlorination (Cupps 2005).

The Yelm area has complex hydrology that makes it especially susceptible to groundwater contamination. The area has multiple aquifers and aquitards, and the Nisqually River influences groundwater flows. Earlier sampling indicated the presence of nitrates in aquifers east of Yelm, so the DOE conducted a background water quality assessment from 1996-97 to determine the extent of contamination prior to implementing use of reclaimed water for groundwater recharge (Cupps 2005).

Table 5. Yelm Groundwater Monitoring Comparison (Averages)

		2004 Monitoring Study			**1998 Baseline**
Analyte	Units	Reclaimed Water (Class A)	C. Park Wells (Rec. Outwash)	Yelm Well #2 (Adv. Outwash)	Yelm Well #2 (Adv. Outwash)
Nitrate-N	mg/L	3.2	3.23	2.9	3.2
TDS	mg/L	302	125	85.2	110
Chloride	mg/L	59.8	19.3	6.0	4.9
Fecal coliform	#/100 mL	ND	6	<2	ND
Ammonia-N	mg/L	ND	0.13	<0.1	ND[a]

(Cupps 2005)

[a] Ammonium-N was measured in two samples in the baseline study at 0.014 and 0.015 mg/L.

In 2004, Yelm conducted a follow-up study to determine the impact of reclaimed water aquifer recharge. The data indicated high quality water with little impact on groundwater quality. The 2004 study did not exactly replicate the earlier sampling operation but, as illustrated in Table 5 (page 36), those samples taken from the Yelm City well # 2 showed no significant change.

Sequim, Washington

The Sequim WWTP is a tertiary treatment plant producing approximately 600,000 gallons per day of Class A water. Sequim uses the reclaimed water for garden irrigation, wetland creation, and for cooling, aeration, and flow augmentation of Bell Creek. Sequim is located on the northeast corner the Olympic Peninsula. It is an ideal study area for PPCPs because close to 50 percent of the population is over the age of 59, and 20 percent is over the age of 65 – making the use of pharmaceuticals higher than the average usage statewide (Johnson, Carey, and Golding 2004).

Samples were collected in 2003 from the reclaimed facility effluent as well as the wells and creeks receiving reclaimed water. The DOE's intent was to determine the potential and extent of pharmaceutical contamination in areas served by reclaimed water (Johnson, Carey and Golding, 2004).

The study found 16 compounds present in the WWTP effluent (see Table 6, page 38). Of these compounds, the most significant was the diabetes drug metformin, a highly soluble compound that ranks as the 15th most prescribed medication in

Table 6 PPCPs in Wells Adjacent to Sequim WWTP Water-Reuse Project

(PPCPs in ug/L, except Estrone and beta-Estradiol in ng/L)

	Sequim WWTP	Bell Meadows Residence	Rhodefer Community	Bell Creek	Bell Creek – Replicate
Sample Type	Effluent	Groundwater	Groundwater	Surface Water	Surface Water
Sample Number	474135	474131	474130	474138	474139
Collection Date	18-Nov-03	17-Nov-03	17-Nov-03	17-Nov-03	17-Nov-03
Collection Time	0745 / 1335	1340	1220	1100	1105
Temp. (^{o}C)	na	10.9	10.5	7.7	na
pH (S.U.)	na	7.2	8.0	7.2	na
Conductivity (umhos/cm)	510	422	328	347	na
TSS (mg/L)	<1	na	na	5	4
Nitrate-Nitrite (mg/L)	na	<0.10	0.17	1.7	2.1
Dissolved Oxygen (mg/L)	na	0.9	0.0	na	na
Acetaminophen	nd	nd	nd	nd	nd
Antipyrine	nd	nd	nd	nd	nd
Caffeine	21	1.0	3.8	nd	nd
Carbamazepine	43	nd	nd	nd	nd
Cimetidine	127	nd	nd	nd	nd
Codeine	12	<LOQ	<LOQ	nd	nd
Cotinine	21	<LOQ	<LOQ	nd	nd
Diltiazem	10	nd	nd	nd	nd
Erythromycin	nd	nd	nd	nd	nd
Fenofibrate	nd	nd	nd	nd	nd
Fluoxetine	nd	nd	nd	nd	nd
Hydrocodone	2.9	nd	nd	nd	nd
Ketoprofen	52	nd	nd	nd	nd
Metformin	97	7.5	3.4	11	12
Nicotine	54	6.3	1.9	25	16
Nifedipine	nd	nd	nd	nd	nd
Paraxanthine	200	nd	nd	nd	nd
Ranitidine	5.1	nd	nd	nd	nd
Salbutamol	60	<LOQ	nd	nd	nd
Sulfamethox-azole	4.2	nd	nd	nd	nd
Trimethoprim	13	nd	nd	nd	nd
Warfarin	nd	nd	nd	nd	nd
Estrone	2.6	nd	nd	0.26	nd
beta-Estradiol	nd	nd	nd	nd	nd

(Johnson, Carey, and Golding, 2004)

na = not analyzed
nd = not detected
<LOQ = below the limit of quantification
*tentatively identified

Washington. It was found in all samples collected for the study. Also found in most of the samples were nicotine and codeine. The nicotine was found, in many cases, to be the result of sample handling procedures. It should be noted that nicotine and codeine are considered ubiquitous compounds and the reclaimed water is not the only source of these compounds in the environment. Sampling found 13 products in the effluent that were not present elsewhere in the environment. The DOE determined that the levels of PPCPs found in the Sequim reclaimed water were at very low levels compared to conventional wastewater treatment effluents (non-tertiary treatment effluent) and below the level of concern (Johnson, Carey, and Golding 2004).

These case studies indicate that reclaimed water is becoming more and more acceptable around the United States. Utilizing state of the art treatment techniques, municipalities are able to reclaim water and preserve valuable sources of water. Protecting stream quality is important to ecosystems, salmon runs, and human health. Urban areas are able to recharge groundwater aquifers and extend their useful supply or prevent intrusion of seawater into the aquifers.

Studies also indicate that the water is safe for reuse. Regulatory authorities place a much higher standard on reclaimed water to safeguard human health and the environment from its effects. PPCPs are still a potential problem in the environment but the small volumes present in effluent and the enhanced removal demonstrated by CTW make reclaimed water a good source of quality water.

4. LOTT PLANT OPERATIONS

LOTT serves Lacey, Olympia, Tumwater and urban Thurston County for wastewater treatment and disposal. As required by the Clean Water Act of 1972, LOTT utilizes primary and secondary treatment on all wastewater to remove settleable and nonsettleable solids, and biological organisms. LOTT also removes nutrients from wastewater as part of its NPDES permit requirements. A portion of that treated water receives tertiary treatment to meet reclaimed water standards (LOTT 2006).

Much of the state Capitol campus irrigation was converted in 2007 to reclaimed water (WA GA 2008). According to the GA's 2008 Sustainability Report, in 2007 over 6,000,000 gallons of reclaimed water irrigated Heritage Park, Marathon Park and along Deschutes Parkway (2008). Figure 1 (page 4) illustrates the location of the Capitol campus that is using reclaimed water.

LOTT plans expansion of reclaimed water use by extending service to the Tumwater Valley Golf Course. This expansion, to be completed in 2010, will double the amount of reclaimed water produced by the Budd Inlet Plant and used in the South Sound (Dodge 2008). This is a positive step for LOTT as it will save groundwater currently pumped for irrigation. Also, the state-of-the-art technology LOTT employs for its processes will keep the public safe while reclaiming water.

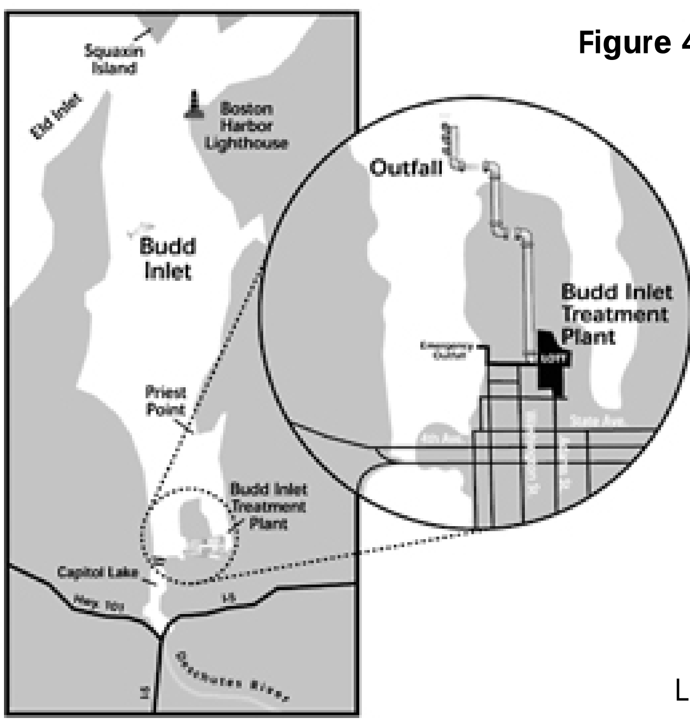
LOTT Budd Inlet Treatment Plant

LOTT operates the Budd Inlet Treatment Plant (the Plant) in downtown Olympia and serves most of the greater Olympia area as well as the communities of Lacey and Tumwater (LOTT 2006). The capacity of the plant is over 28 MGD (peak wet weather capacity) with an average treatment of 15 MGD (LOTT 2009a).

The Plant operates under NPDES Permit #WA0037061, issued in 2005. This permit mandates treatment levels for all wastewater discharged from the treatment plant as well as treatment standards for reclaimed water (WA DOE 2005). The Plant discharges wastewater effluent into Budd Inlet. Figure 4 (page 43) illustrates the discharge of wastewater effluent.

Since Budd Inlet is especially vulnerable to eutrophication from conventional wastewater discharge during the summer and shoulder seasons (April, May and October), the permit identifies loads for biochemical oxygen demand (BOD) and total inorganic nitrogen in terms of pounds per day rather than as a flow discharge. Table 7 (page 44) summarizes the NPDES maximum limits for conventional wastewater. LOTT's maximum levels during summer and shoulder seasons for BOD and TIN are expressed in terms of pounds per day (lb/d) as opposed to milligrams per liter (mg/L) the rest of the year. Regardless of the flow volume through the plant, during summer and shoulder seasons LOTT must meet the lb/d load. As the flow increases into the treatment plant, the load also increases; therefore, the greater the flow, the more efficient the plant must be at removing BOD and TIN (LOTT 2006). LOTT is not required to monitor for nitrates and total suspended solids during summer and shoulder seasons or to monitor for total inorganic nitrogen during winter (WA DOE 2005).

Figure 4: Budd Inlet Discharge



LOTT 2009a

LOTT projects an increase to 22 MGD average influent to the plant by 2025, which would cause LOTT to exceed its permitted load for both BOD and TIN at current discharge rates (9 mg/L and 3 mg/L respectively). LOTT therefore plans to build satellite reclamation plants (SRPs) to draw flow from the Budd Inlet Plant, treating to Class A water standards. Diverting the increase will keep LOTT at its current discharge load into Budd Inlet and within the permit limitations (LOTT 2006).

Table 7. NPDES Permit Summary, Budd Inlet Treatment Plant, Effective October 1, 2005[1]

	Seasonal Condition		
Parameter	**Summer[2]**	**Shoulder[3]**	**Winter[4]**
BOD	671 lb/d	900 lb/d	30 mg/L
TIN	288 lb/d	338 lb/d	--
NH3	--	--	26 mg/L
TSS	--	--	30 mg/L
Fecal Coliform	200 per 100 ml sample		
Total Recoverable Copper	0.006 mg/L		
pH	Between 6-9		

1. All values refer to monthly averages. Certain parameters also have weekly or daily limits.
2. Summer = June, July, August, September
3. Shoulder = April, May, October
4. Winter = November, December, January, February, March

(LOTT 2006, ES-2)

Hawks Prairie Reclaimed Water Satellite

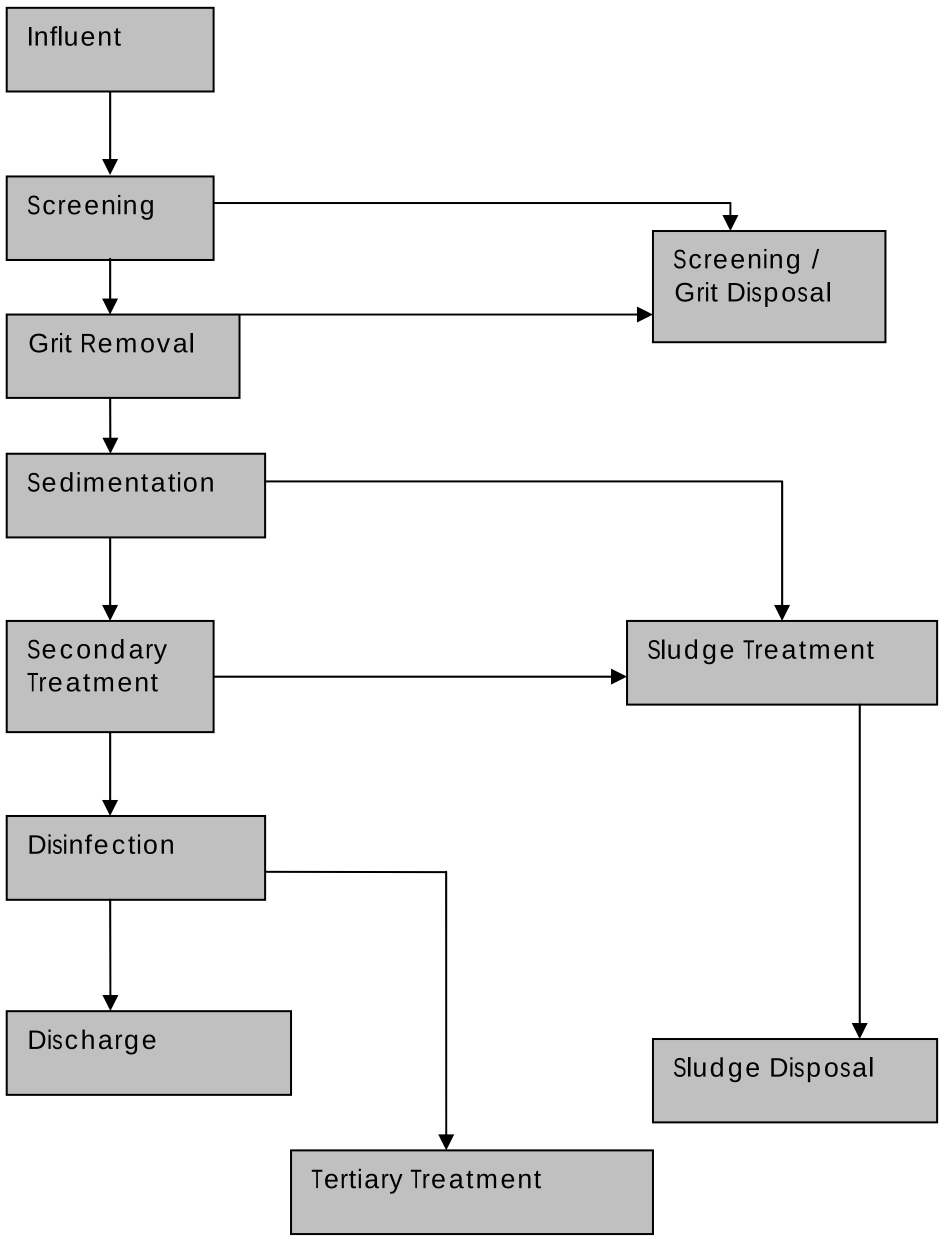
Limited area for expansion in downtown Olympia led LOTT to expand operations to satellite plants. The Hawks Prairie (Lacey) Reclaimed Water Satellite (Satellite) is the first of the planned satellites to come online (LOTT 2006).

The Satellite treats approximately 2 MGD of wastewater that originate in Lacey. LOTT treats this water to Class A standards and discharges it to a CTW/recharge basin area on Hogum Bay Road also in Lacey. This 41-acre facility is used to store reclaimed water for use in irrigation and toilet flushing. That water not pumped for other purposes flows to recharge basins where it percolates 90 feet through the soil and enters the groundwater aquifer. LOTT installed 10 monitoring wells to track the quality of the water present in the aquifer (WA DOE 2006).

The Satellite operates under Ecology Permit ST6206. In addition to meeting the requirements outlined under the Plant requirements, the Satellite must meet groundwater discharge criteria (see Table 4, page 35).

Additional benefits of the Hogam Bay facility include both public education and habitat creation (WA DOE 2006). The area is aesthetically pleasing and it features a walking trail with information boards providing visitors with background information on the water treatment processes. The area also developed into a habitat area for birds and a variety of aquatic plants and animal species.

Figure 5 Wastewater Treatment Plant Flow



Nathanson 2008, page 288

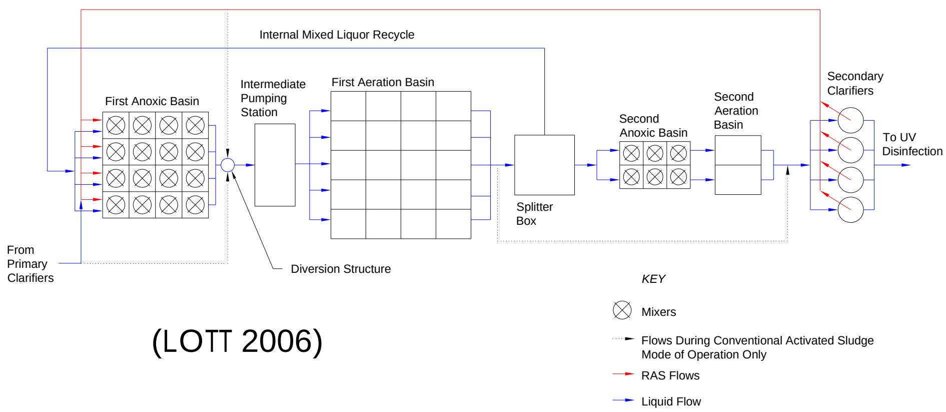
LOTT Treatment Process

The influent enters through the plant headworks and undergoes preliminary treatment, consisting of large debris and grit removal. The wastewater then flows into primary sedimentation tanks, where the floating materials are skimmed off the top. The heavier materials settle to the bottom, where they are pumped out as sludge. See Figure 5 (page 46) for a water flow diagram.

In a typical wastewater treatment plant, the influent would then undergo a biological (or secondary) treatment process using activated sludge to remove solids that did not settle in the primary process (Nathanson 2008). However, at the LOTT plant, processes change from the typical during the secondary treatment phase. In order to meet its NPDES permit limit, LOTT must remove both organic carbon and nitrogen during summer and shoulder seasons. Class A Reclaimed Water production also requires nitrogen removal – as LOTT increases Class A production, they expanded nitrogen removal to year round as opposed to only summer and shoulder seasons (LOTT 2006).

LOTT utilizes the Bardenpho™ process for nitrogen removal (see Figure 6, page 49), consisting of two alternating treatments in anoxic and aeration basins. Alternating anoxic and aerobic environments allows both nitrification and denitrification to occur sequentially. Organic nitrogen and ammonia are nitrified into nitrate and nitrite in the aerobic basin. The nitrified water is recycled to the anoxic basin where denitrifying organisms reduce the nitrate to nitrogen gas. Any nitrates not removed in the first basin will be removed in the second anoxic basin. Water is re-aerated in the second aeration basin prior to clarification (LOTT 2006). Clarification removes residual solids from the treated water. Water enters through the center of the tank where it then radiates out to the edges. The residual bacteria and solid material (activated sludge) fall, while the clarified water flows over weirs and into a collection trench. Effluent from the secondary clarifiers generally has a suspended solids concentration below 10 mg/L (limit 30 mg/L). The clarified water is then pumped to disinfection. LOTT utilizes ultraviolet light for disinfection to keep the coliform levels within permit limits (LOTT 2006).

FIGURE 6: Bardenpho© Four-Stage Biological Treatment



(LOTT 2006)

The Budd Inlet plant has a 1.5 MGD reclaimed water treatment capacity. Water intended for additional treatment is pumped toward the sand filters. The pipeline includes chemical injection ports where sodium hypochlorite and a coagulant are flash mixed into the water upstream of the filters. This provides additional disinfection as well as increased filtering efficiency by coagulating the solids still present in the water. The water is then forced through the sand filters and the filtered water is pumped to basins where the water remains for 30 minutes, undergoing chlorine disinfection. Washington State requires a chlorine residue in all reclaimed water of 0.5 mg/L. Solely using UV will not allow for that chlorine residual. LOTT continually monitors the effluent for compliance. The resulting reclaimed water meets Class A standards (LOTT 2006).

LOTT achieved 100 percent compliance with all permit limitations in 2008 and has an excellent compliance record overall (LOTT 2009a). LOTT's permit limitations included removal of microorganisms, suspended solids and nutrients. The DOE determined that, although organic chemicals and heavy metals are present in the effluent, they are within acceptable levels for discharge into the environment (WA DOE 2005).

PPCPs, however, are not a category identified in the WWTP permit since this is a relatively new category of concern. In 2008, LOTT participated in a study conducted by the EPA to test the levels of PPCPs present in wastewater effluent. Earlier studies suggested that biological nutrient removal processes are more effective in PPCP removal than conventional treatment processes. EPA collected samples of influent, effluent, biosolids and reclaimed water from the LOTT process as well as from two facilities that do not utilize nutrient removal but which also discharge into Puget Sound. They will compare the data to test whether nutrient removal helps in the removal of PPCPs. The results will be available sometime in 2009 and, although this is a very small study with a small sample size, LOTT hopes those results will provide more information regarding PPCPs and removal effectiveness through advanced biological treatment (LOTT 2009a).

LOTT employs state-of-the-art treatment processes for both wastewater and reclaimed water effluent. In 2008, LOTT won both the National Association of Clean Water Agency (NACWA) Excellence in Management Award and the Thurston County Green Business Award, in part for its reclaimed water operations. NAQWA also awarded LOTT its Silver Level Peak Performance Award in 2008 for LOTT's excellence in meeting permit requirements (LOTT 2009a).

LOTT's reclaimed water meets or exceeds all permit requirements for groundwater recharge, irrigation and all non-potable uses. Expanding reclaimed water use is a responsible choice for the LOTT service area.

5. COMPARATIVE ANALYSIS

In this chapter, LOTT operations will be compared with those facilities described in chapter 3. After briefly reviewing each case study operation, I will describe how LOTT's treatment processes and effluent characteristics compare.

The only illnesses directly related to reclaimed water happened in Arizona in 1979. This outbreak was caused by a cross-connection between the reclaimed water used for watering trees and shrubs in a campground and the potable supply for that campground (WA DOH 2007). LOTT utilizes a dual distribution system to ensure this will not happen in Thurston County. It also color codes the distribution pipes so that a cross connection is extremely unlikely. In accordance with DOE and DOH requirements, LOTT paints in purple all pipes and appurtenances related to reclaimed water (LOTT 2009b).

The first case study reviewed earlier involved LA County wastewater treatment plants, which use coagulation and chlorination, followed by filtration as a tertiary process, with an additional chlorination treatment (Hartling and Nellor 1998). The LA County Sanitation District's reclaimed water meets drinking water criteria for heavy metals, pesticides, trace organics and radioactivity. This effluent contains less than 1 coliform bacterium per 100 mL. Virus sampling was conducted on 981 samples of tertiary effluent from 1979 – 1998 and only one sample tested positive for a virus (Hartling and Nellor 1998). No data were recorded for PPCPs in the reclaimed water output. The LA County Sanitation district does not utilize nutrient removal in its treatment process. This can lead to a variety of issues, including algae growth in storage ponds and increased nitrogen in groundwater (Hartling and Nellor 1998).

Similarly to LA County, LOTT's Budd Inlet Plant also uses an additional coagulant and disinfection prior to filtration. LOTT also disinfects the water after the filtration operation for a minimum of 30 minutes to achieve a state-mandated chlorine residual (LOTT 2009a). In 2008, LOTT's reclaimed water output met all permit requirements for microorganisms, suspended solids and nutrients. Sampling detected organic chemicals and heavy metals in the effluent but at levels DOE considers below concern for the receiving environment (LOTT 2009a; WA DOE 2005).

A specific benefit LOTT has over LA County is LOTT's nutrient removal prior to initiating the tertiary treatment process. This advanced secondary treatment removes nitrogen through a biological process that alternates anoxic and aerated conditions (LOTT 2006). This additional treatment makes LOTT's reclaimed water less likely to cause environmental degradation through algae blooms and eutrophication than the water released by LA County.

The next case study involved the Irvine (CA) Ranch Water District (IRWD). By 1998, IRWD was distributing reclaimed water to landscape irrigation, recreational uses and toilet flushing (Young et al. 1998). IRWD's NPDES permit requires an average of less than 2.2 coliforms per 100 mL over a one-week period. The IRWD reclaimed water meets all California reuse requirements. The method used for tertiary treatment is the same as in LA County. IRWD does treat for nutrients in tertiary effluent. This led to the resolution of several quality problems in its reclaimed water reservoirs, including increased turbidity levels and algae growth (Young et al. 1998).

Like IRWD, LOTT's reclaimed water meets all permit requirements (LOTT 2009a). This includes meeting an average 2.2 MPN/100mL over a one-week period with a 23 MPN/100mL sample maximum (MPN = most probable number of microorganisms present in effluent) (WA DOE 2005). This value is comparable to IRWD's effluent.

The next case study reviewed was the St. Petersburg, FL, reclaimed water system. St. Petersburg reclaims wastewater for irrigation of golf courses and for a deep-injection well system. In 1989, the city achieved its goal of zero discharge of wastewater effluent to receiving waters. The deep well disposal is only used when storage capacity is full at the appropriate facilities. St. Petersburg's treated effluent undergoes filtration and chlorination prior to discharge. The St. Petersburg City Council commissioned a study that determined "there is no evidence of increased enteric disease in urban areas irrigated with treated reclaimed water..." or from any aerosols from spray irrigation (Johnson and Parnell 1998, 1055). Elevated levels of nitrogen and phosphorus, trace amounts of calcium, magnesium and iron are present in the reclaimed water, which is considered a selling point for the water when used for landscaping (Johnson and Parnell 1998).

Again, LOTT's use of advanced secondary treatment for nutrient removal leads to a superior water quality for discharge. But, the majority St. Petersburg's water is used for irrigation not discharge. This may lead to a cost savings for golf course operators – less fertilizer to apply – but runoff or injection could lead to eutrophication in receiving waters.

The goal of Orange County's reclaimed water program is to maximize the availability of high-quality groundwater in the OCWD. Specifically the county wants to reduce the amount of water imports necessary for Orange County (Mills, Bradford, Rigby, and Wehner 1998).

Since OCWD discharges reclaimed water into aquifers, it is required to perform more stringent treatment than a standard WWTP (see Table 3, page 32). The treated effluent is chemically clarified by the addition of lime to the stream achieving a pH of 11.2 followed by rapid mixing, flocculation and sedimentation. This removes over 99 percent of coliform bacteria, 26 percent of total organic compounds, and significantly reduces the inorganic compounds. OCWD conducts extensive testing for microbial, organic and inorganic contaminants. Water quality from the OCWD treatment plants consistently meets or exceeds drinking water standards (Mills, Bradford, Rigby, and Wehner 1998).

LOTT does not perform direct discharge of reclaimed water into a drinking water aquifer. Rather, LOTT spreads water over a CTW and then pumps it into recharge basins. The reclaimed water then percolates through soil and into the aquifer (LOTT 2009a). Because this reclaimed water is used in the recharge basin, it must meet additional requirements (see Table 4, page 35) (WA DOE 2006). Orange County must meet more stringent requirements than LOTT for removal of a variety of contaminants (see tables 3 and 4 on pages 20 and 28 for comparison.)

There are four criteria where Orange County is more stringent than Washington DOE requirements and one where LOTT's permit is more stringent than Orange County. Although most of Orange County's requirements are more stringent than LOTT's, Orange County does a direct injection into aquifers while LOTT utilizes a recharge basin. Water passing through a recharge basin into the aquifer will undergo additional filtration and the resulting water meets all drinking water standards (Nathanson 2008; WA DOE 2006).

A study in northeastern Spain focused on the presence of PPCPs in CTWs. Researchers studied influent and effluent at a small urban CTW near the Mediterranean Sea for 8 PPCPs. The removal efficiency for these compounds varied widely from 35 percent to 98 percent. Researchers also noted benefits, as the CTW greatly enhanced the biodiversity of the area. The natural processes appeared to be an efficient method for reclaiming water (Llorens, Matamoros, Domingo, Bayona, and Garcia 2009). Currently, there are no data regarding PPCPs in LOTT's reclaimed water but a study is pending to identify process efficiency (LOTT 2009).

The Yelm study illustrates the effectiveness of the Department of Ecology's strict standards regarding reclaimed water used for groundwater recharge (see Table 4, page 35). All of Yelm's reclaimed water must meet Class A standards and must undergo biological nitrogen reduction. Like LOTT, Yelm employs nitrogen removal during secondary treatment, followed by filtration, mixing and chlorination. The effluent is then pumped to a CTW and recharge basin (Cupps 2005).

In 2004, DOE funded a study to determine the impact of using reclaimed water for aquifer recharge. That study indicated high quality groundwater with little impact from reclaimed water (Cupps 2005).

LOTT and Yelm must meet the same criteria prior to discharge to a recharge basin, as both must meet the same DOE requirements. Significantly, both Yelm and LOTT must utilize advanced secondary treatment for nutrient removal, and sampling shows that this removal is effective in maintaining high quality groundwater supplies (WA DOE 2006; Cupps 2005).

The Sequim WWTP is a tertiary treatment plant producing reclaimed water for garden irrigation, wetland creation, and for cooling, aeration, and flow augmentation of a local creek. Sequim made an ideal study area and, in 2003 DOE took samples from the reclaimed water treatment facility effluent, as well as from the wells and creeks receiving reclaimed water, to determine the potential and extent of pharmaceutical contamination (Johnson, Carey, and Golding 2004). As previously stated, DOE determined that these levels were very low compared to conventional wastewater treatment effluents (non-tertiary treatment effluent) and below the level of concern (Johnson, Carey, and Golding, 2004). LOTT participated in an EPA-sponsored study in 2008 to determine the effectiveness of its treatment process for PPCP removal. At this time, those data are not yet available (LOTT 2009a) but, as LOTT has processes similar to those at Sequim (and must meet the same permitting standards) it is reasonable to infer at least comparably low levels of PPCPs in its effluent.

LOTT utilizes state-of-the-art processes that compare favorably with other providers of reclaimed water. Other municipalities have used reclaimed water for decades. LOTT adopted many similar or better processes for its operations when it upgraded to tertiary treatment plant operations. The discharge limits are similar among those providers in the United States and the reclaimed water produced at the LOTT facilities meets all permit limits for pathogenic microbes, organic compounds, and nutrients. LOTT's reclaimed water is as safe for use as that discharged from other municipalities.

6. CONCLUSION

Using reclaimed water for irrigation, groundwater recharge or any sub-potable use is a worthwhile financial and structural investment for municipal facilities. Its use can help an urban area conserve the precious water resources required for expanding populations, replacing potable water currently diverted for those purposes. Climate change may lead to water resource scarcity, making reclaimed water even more important.

Questions remain about the safety of reclaimed water and whether or not LOTT should expand reclaimed water distribution in South Puget Sound. Dangers discussed in chapter 2 included microorganisms, organics, inorganics, and PPCPs. LOTT meets all its permit requirements for those contaminants and discharge levels in effluent are at levels that DOE has determined are well below levels of regulatory concern.

LOTT disinfects Class A water three times, using UV light and two doses of sodium hypochlorite; one dose includes a 30 minute contact basin to ensure a 0.5 mg/L residual in the distribution lines. LOTT also meets all requirements for inorganics and organics. The main unknown remains what PPCPs are present in the reclaimed water. There is no permit standard for PPCPs in LOTT's NPDES permit. Since PPCPs may cause health and ecosystem problems, LOTT proactively participated in an EPA study to determine the effectiveness of its treatment methods for PPCP removal. Unfortunately, the results of that study are not yet available. Other studies indicate PPCPs are present in Class A water but well below health concern levels. PPCPs may accumulate in the ecosystem, however, and cause problems later.

Regardless of the problems that may result from PPCPs or other contaminants that may pass into the environment through reclaimed water, LOTT should continue with its planned expansion into Tumwater and other areas. Wastewater will still be discharged into the environment, specifically Budd Inlet, if the water is not reclaimed. Reclaimed water is subjected to more rigorous treatment standards using filtration and chlorination. The tertiary treatment removes significantly more contaminants than conventional treatment methods, making it a better choice for the environment.

LOTT, DOE, and the EPA should all continue to study the various treatment methods to enhance removal of PPCPs before they reach the environment, developing additional detection methods for PPCPs. Also, educating the public about proper disposal of pharmaceuticals and the potential hazards of household products that make their way into the wastewater stream should be a priority. Studies should continue with regard to the impacts that PPCPs have on the environment, and including PPCPs in the NPDES permitting process should be considered as well.

LOTT compares very well with reclaimed water providers in other areas of the country. It utilizes similar methods for water treatment and achieves comparable results. LOTT meets the stringent standards for required discharge and reclaimed water.

Increasing reclaimed water use will save precious water resources in the South Sound for salmon habitat, riparian ecosystems and potable use. LOTT's reclaimed water product is safe for non-potable uses and LOTT should expand its service area. With our growing population and decreased water resources, we cannot maintain the luxury of using water only once.

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