

The Role of Contaminants of Emerging Concern in Aquifer Recharge Projects Using Reclaimed Water:

LOTT Clean Water Alliance Case Study

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Jeff Hansen, Project Manager, HDR

Acknowledgements:

Wendy Steffensen, Environmental Project Manager, LOTT

Ida Fischer, Hydrologist, HDR

Presentation Outline

- LOTT and the Reclaimed Water Infiltration Study
- Notes on Interpreting Findings
- Task 1 Results (Water Quality Characterization)
- Task 2 Activities (Treatment Effectiveness Evaluation)
- Next Steps



**LOTT
Facilities**

Budd Inlet Treatment Plant



Martin Way Reclaimed Water Plant



Reclaimed Water Uses:

- Irrigation
- Golf Course
- Water Feature (wading stream)
- Aquifer Recharge (including for water rights mitigation)



Reclaimed Water Infiltration Study

Residual chemicals in the news

Community concerns

Drugs found in salmon, from tainted wastewater

Samples collected in Tacoma and Bremerton show 81 drugs and personal-care products

Scientists don't know if high levels because of residents' drug use or wastewater-treatment processes

Findings don't indicate threat to human health

BY LYNDA V. MARDER

Pigeon Creek, a tributary of the Puget Sound, is the source of the contaminated water that flows into the estuary near the outfalls of sewage-treatment plants and effluent sampled at the plants were cocktails of 81 drugs and personal-care products with levels detected among the highest in the nation.

The medicine chest of common drugs included Fluoxetine, Aleve, Tylenol, Percocet, Valium, Zofran, Tagamet, OxyContin, Darvon, nicotine, caffeine, fungicides, antiseptics, anticoagulants and antibiotics.

Why are the levels so high? It could be because people here use more of the drugs detected, or it could be related to

shown that juvenile chinook migrating through contaminated estuaries in Puget Sound die at twice the rate of fish elsewhere.

The drugs detected in the study could be part of the reason, as they have the potential to affect fish growth, behavior, reproduction, immune function and antibiotic resistance.

The drugs selected for testing were:

...but, and levels could be higher or lower depending on people's use of drugs and volumes of treatment-plant discharge.

For instance, levels of deet (an insect repellent) and antihistamines are probably even higher in summer.

Some regional differences were detected.

Substantially higher concentrations of deet, caffeine, ibuprofen and female reproductive hormone were found in Bremerton compared

...the area

...that dis-

...ers.

The amount of drugs and chemicals from all plants into Puget Sound is because so little is known about them.

However, "you have to wonder what it is doing to the fish," Meador said. His other recent work has

...SEE DRUGS, SA

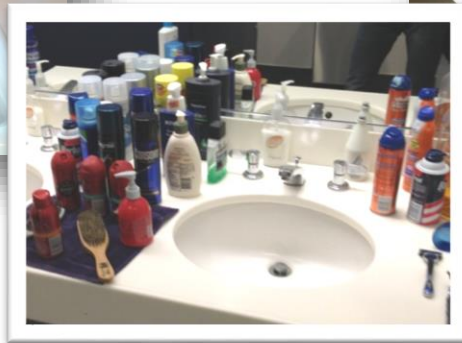
Drugs, household chemicals are a risk 'we haven't fully begun to understand' (The Olympian)

Keep Drugs Out of the Water Supply (Parade)

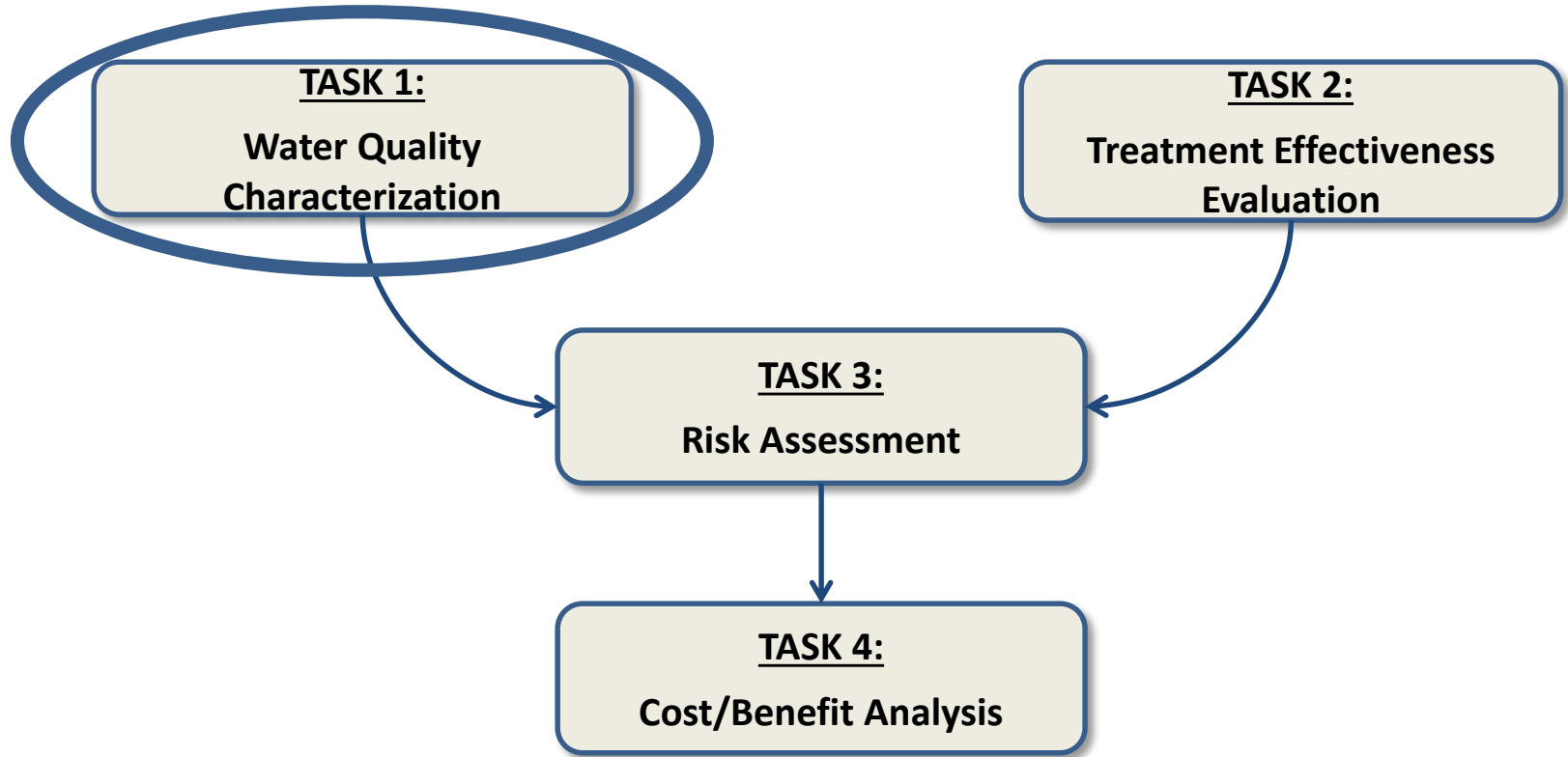


Primary Study Question

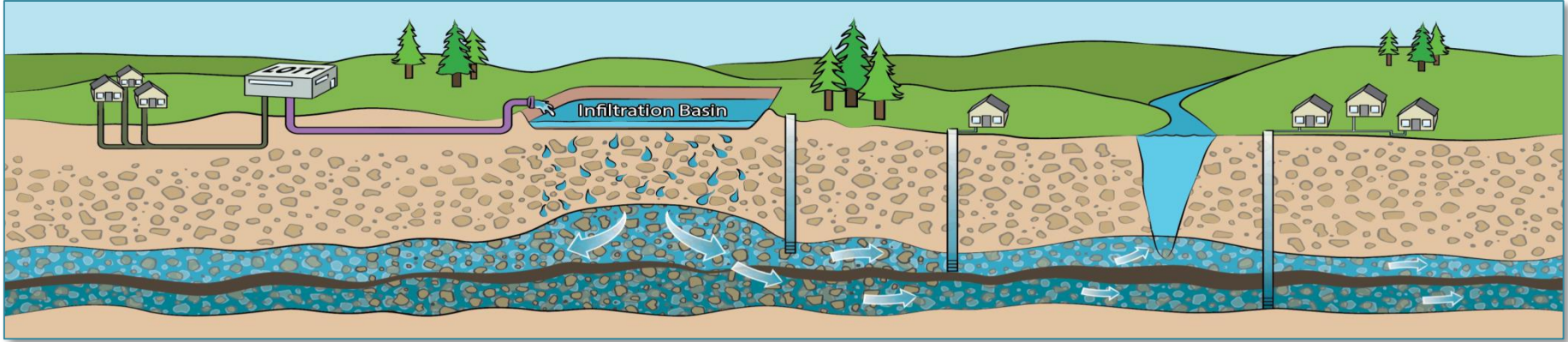
What are the risks from infiltrating reclaimed water into groundwater because of chemicals that may remain in the water from products people use every day, and what can be done to reduce those risks?



Study Framework

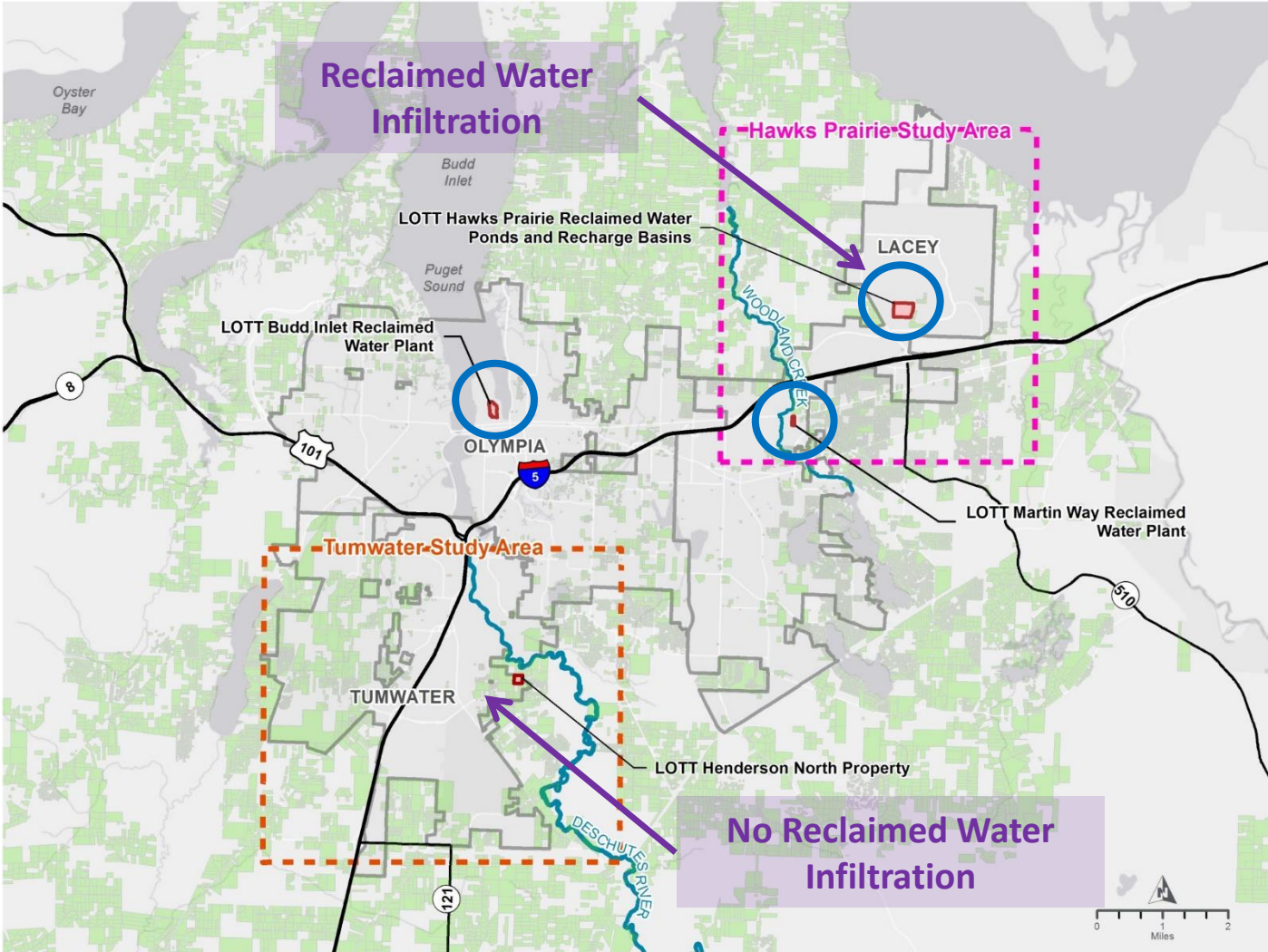


Water Quality Characterization



- 1) Wastewater / Reclaimed Water
- 2) Groundwater
- 3) Surface Water

Study Area (Task 1)



- 2 treatment plants
 - Martin Way
 - Budd Inlet
 - 4 sampling events (seasonal)
- 2 groundwater areas
 - Hawks Prairie (28 locations)
 - Tumwater (30 locations)
 - 1 sample per location
- 2 surface water basins
 - Woodland Creek (6 locations)
 - Deschutes River (6 locations)
 - 4 sampling events
 - Low-flow (2)
 - “First Flush” (after rain event)
 - High-flow

Sampling List

Regulated Parameters

- Pathogens (bacteria, viruses)
- Nutrients (nitrogen, phosphorus)
- Drinking Water Parameters (inorganics, organics, metals, etc.)
- Other (temperature, dissolved oxygen, etc.)

Unregulated Parameters* (Residual Chemicals)

- Medicines (anti-seizure, analgesics, antibiotics)
- Personal Care Products / Foods (sucralose, caffeine, anti-microbials)
- Hormones (estrogenic, steroid)
- Household Chemicals (flame retardants, pesticides, perfluorinated compounds)
- 127 unregulated chemicals in total

* Meaning, unregulated in drinking water or wastewater

In total, 409 parameters measured

Scale / Concentration

Concentration	Units	Examples
1 part per million (ppm)	1 milligram/Liter (mg/L)	one drop in 10-gallon bucket one second in 12 days
1 part per billion (ppb)	1 microgram/Liter ($\mu\text{g/L}$)	one drop in 2 tanker trucks one second in 32 years
1 part per trillion (ppt)	1 nanogram/Liter (ng/L)	one drop in 16 olympic pools one second in 32,000 years

Interpreting findings:

Analytical noise

- Low concentrations often near detection limits
- Inherent variability in these chemicals over time
- Interference from other organics in complex samples (e.g., wastewater)



Wastewater / Reclaimed Water Quality Characterization



Budd Inlet
Reclaimed Water Plant

Martin Way Satellite
Reclaimed Water Plant



Wastewater Characterization

- Raw wastewater at Martin Way and Budd Inlet very similar in Residual Chemical makeup
- Residual Chemicals observed at highest concentrations in wastewater in all sampling events at both plants:
 - **Acesulfame-K**
 - **Acetaminophen**
 - **Caffeine***
 - **Iohexol**
 - **Metformin**
 - **Sucralose**
 - **Theobromine**

* = Non Detect in Reclaimed Water

Summary of Residual Chemical Detections

(Number of Detections at Various Stages of Treatment)

	1 st Sampling (11/2014)	2 nd Sampling (02/2015)	3 rd Sampling (05/2015)	4 th Sampling (08-10/2015)
Martin Way Reclaimed Water Plant				
WW temperature lower in Event 1 (14°C versus 17-19°C for Events 2-4)				
Wastewater	65	49	49	44
Reclaimed Water	47	27	30	30
Exiting Wetlands	25	NA	NA	28
Budd Inlet Reclaimed Water Plant				
Biological Nutrient Removal (BNR) in full operation during Events 2-4; not Event 1				
Wastewater	67	55	50	39
Secondary Effluent	NA	33	NA	28
Reclaimed Water	40	25	23	27

Total number of Residual Chemical analytes = 127

NA = Not Included in Sampling Event

Residual Chemicals Consistently Removed by Treatment to Levels Below Detection*

Chemical	Type	Chemical	Type
1,7-Dimethylxanthine	Caffeine Degradate	Erythromycin	Antibiotic
Acetaminophen	Analgesic	Estrone	Hormone
Amoxicillin	Antibiotic	Ethylparaben	Preservative
Butylparaben	Preservative	Ibuprofen	Analgesic
Caffeine	Stimulant	Propylparaben	Preservative
Cimetidine	H2 Blocker (Heartburn)	Triclosan	Antibacterial

** Present in wastewater at both facilities in at least 3 of the 4 sampling events, and removed to below detection in at least 3 of the 4 events.*

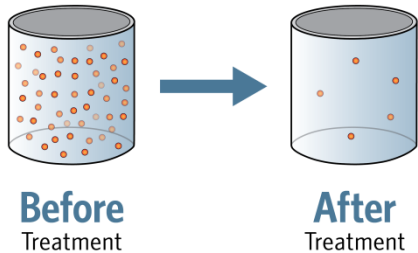
Residual Chemicals Consistently Detected in Reclaimed Water*

Chemical	Type	Chemical	Type
1,4-Dioxane	Solvent	Iopromide	X-ray Contrast Agent
Acesulfame-K	Artificial Sweetener	Lopressor	Beta Blocker
Atenolol	Beta Blocker	Metformin	Anti-diabetic
Carbamazepine	Anti-seizure	Primidone	Anti-convulsant
Cotinine	Nicotine Degradate	Sucralose	Artificial Sweetener
Fluoxetine	Anti-depressant	TCEP	Flame Retardant
Iohexol	X-ray Contrast Agent	TCPP	Flame Retardant

** Present in reclaimed water at both facilities in all 4 sampling events.*

Reclaimed Water Residual Chemical Concentrations and Removal Efficiencies

Removal > 85%



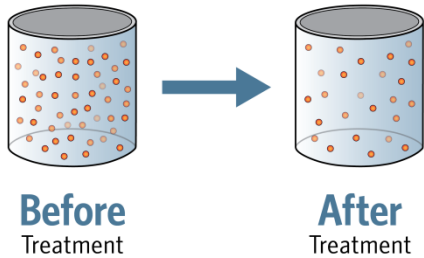
Chemical	Martin Way		Budd Inlet	
	Average Concentration (ng/L)	Average % Removal (RW Compared to WW)	Average Concentration (ng/L)	Average % Removal (RW Compared to WW)
Acesulfame-K	520	99	6,581	86
Metformin	1,263	99	618	99
Atenolol	71	96	205	86
Cotinine	27	99	52	98

Note:

Considers only those Residual Chemicals detected at both plants, in all four sampling events

Reclaimed Water Residual Chemical Concentrations and Removal Efficiencies

Removal = 33-85%



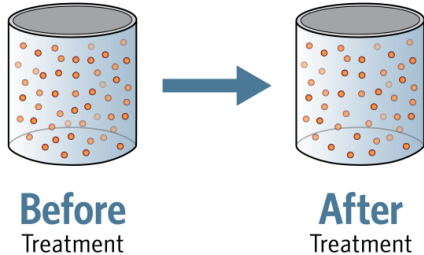
	Martin Way		Budd Inlet	
Chemical	Average Concentration (ng/L)	Average % Removal (RW Compared to WW)	Average Concentration (ng/L)	Average % Removal (RW Compared to WW)
Sucralose	51,250	51	34,250	48
Carbamazepine	233	34	273	32
Fluoxetine	47	53	48	46
Lopressor	238	54	188	49
Primidone	139	NC	165	38
Iohexol	445	87	10,250	31
TCPP	318	67	608	NC

Notes:

Considers only those Residual Chemicals detected at both plants, in all four sampling events
 NC = Not Calculated (concentration in WW less than RW)

Reclaimed Water Residual Chemical Concentrations and Removal Efficiencies

No Removal*



	Martin Way		Budd Inlet	
Chemical	Average Concentration (ng/L)	Average % Removal (RW Compared to WW)	Average Concentration (ng/L)	Average % Removal (RW Compared to WW)
1,4-Dioxane	723	NC	425	NC
Iopromide	151	NC	50	NC
TCEP	102	NC	121	NC

Notes:

Considers only those Residual Chemicals detected at both plants, in all four sampling events

*NC = Not Calculated (concentration in WW less than RW)

Summary of Reclaimed Water Concentrations and Comparisons

- Concentrations of Residual Chemicals in LOTT's reclaimed water are similar to those reported in other facilities' reclaimed water and secondary effluent
- In many cases, LOTT's concentrations are on the low end of literature values
- A notable exception is Iohexol, an x-ray contrast agent, which was observed in LOTT water at higher concentrations than reported elsewhere

Concentrations (ng/L) and Detection Frequencies (%) for Consistently Detected Residual Chemicals in Treated Wastewater and Reclaimed Water				
			Unpublished Data from Other Utilities ⁽³⁾	
	LOTT Results ⁽¹⁾	Published Literature ⁽²⁾	95 th Percentile	Detection Frequency
Acesulfame-K	23 – 13,000	20,000	70,000	98%
Sucralose	18,000 – 68,000	27,000	80,000	96%
Atenolol	36 – 230	260 – 2,440	1,000	82%
Carbamazepine	190 – 300	97 – 1,600	400	90%
Fluoxetine	31 – 65	8 – 78	150	70%
Primidone	64 – 200	90 – 159	300	87%
Iohexol	240 – 14,000	41 – 4,780	11,000	86%
TCEP	39 – 200	200 – 1,400	900	88%

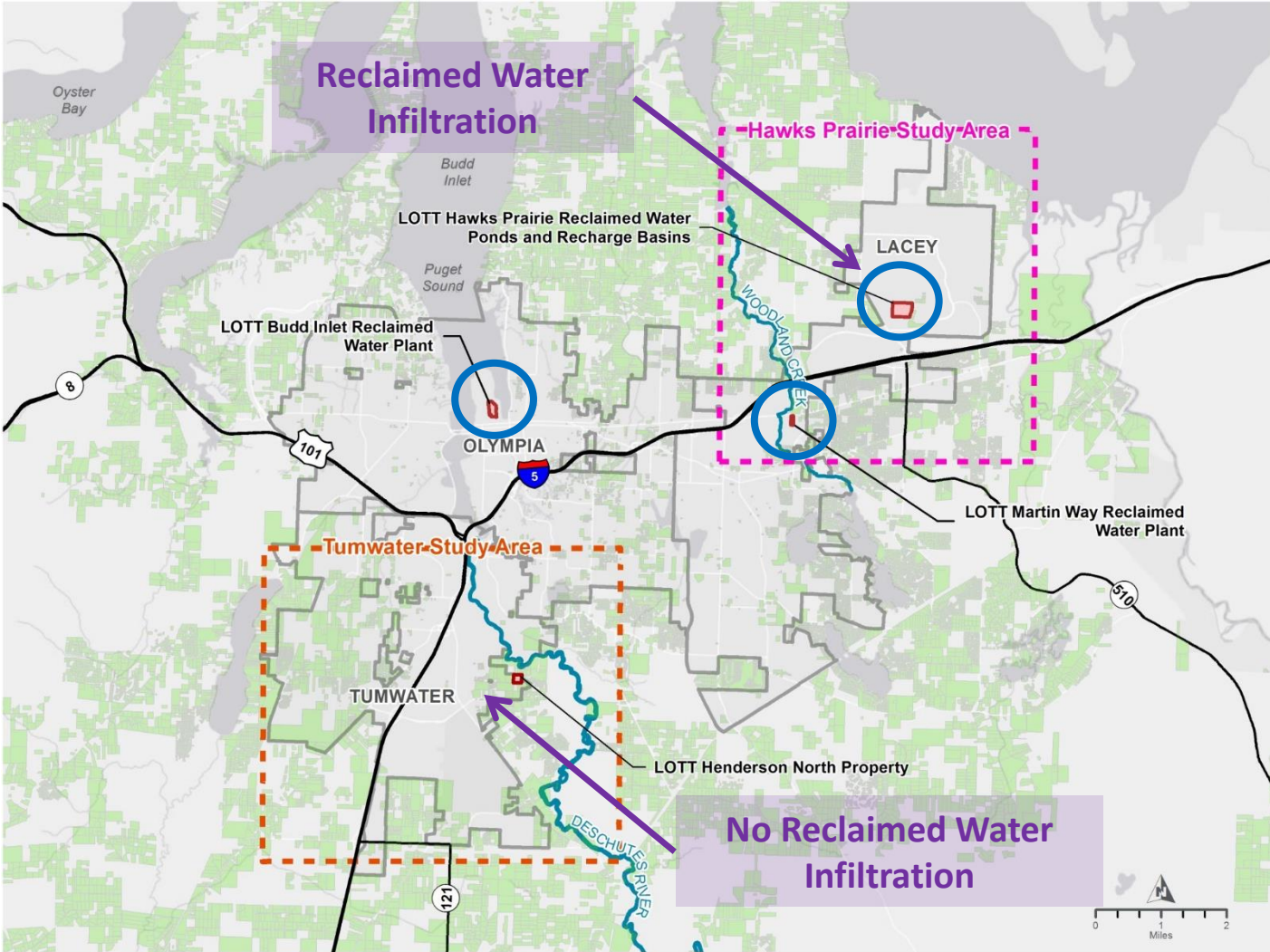
(1) Data from LOTT study; reclaimed water only.

(2) Data from ~100 treatment facilities (including secondary treated wastewater and reclaimed water), as documented in nine studies.

(3) Data from ~225 samples (reclaimed water only), analyzed by EEA (the lab contracted for LOTT's study). 95th percentile concentrations shown (i.e., concentrations in 95% of samples were less than the displayed value).

Reclaimed Water Quality Summary

- Chemicals found in reclaimed water come from everyday products that we use
- Some chemicals are effectively removed by LOTT's treatment processes, while other are fairly recalcitrant
- LOTT's reclaimed water quality is similar to that of other facilities
- *Additional observation:* LOTT's data support literature findings that longer treatment times and older microorganisms (i.e., higher Solids Retention Time, or SRT) result in greater removal of residual chemicals



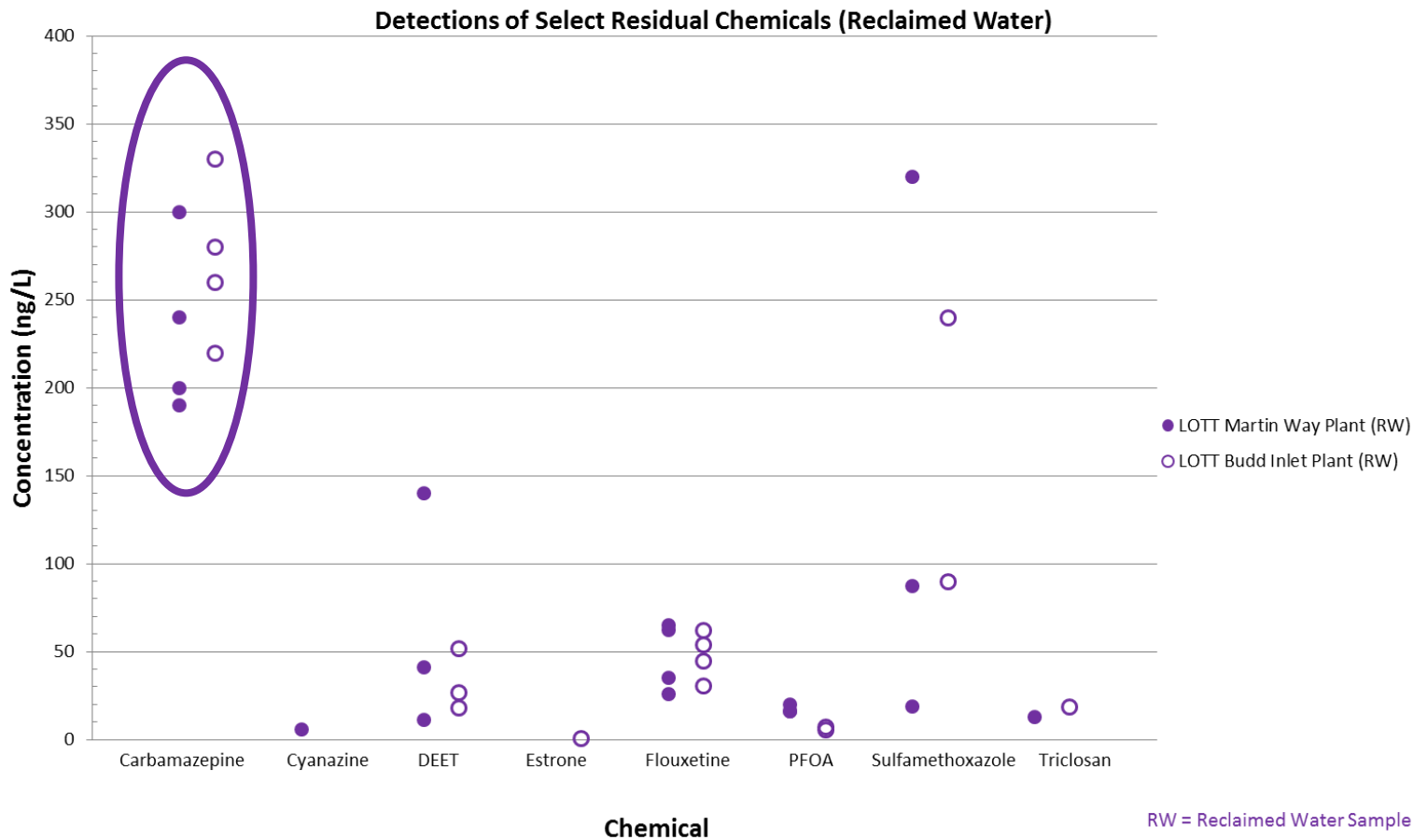
Study Areas

Groundwater
Surface Water

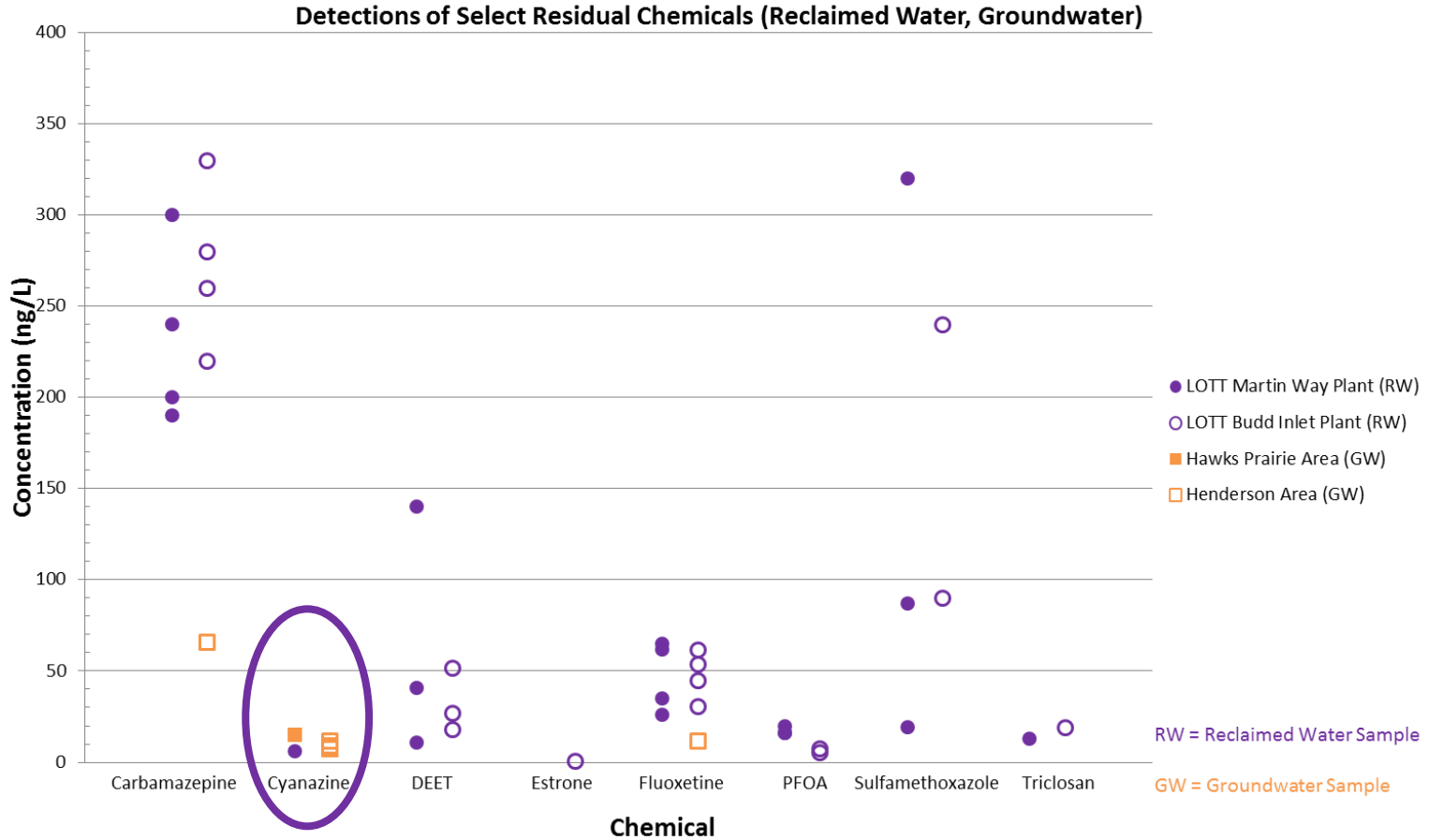
Groundwater and Surface Water Quality

- Chemicals detected:
 - Groundwater: 22
 - Surface Water: 15
- Chemicals most commonly detected at highest concentrations:
 - Artificial sweeteners, flame retardants, select pharmaceuticals (metformin, carbamazepine)
- Potential sources are septic systems, stormwater runoff, and reclaimed water (where it is discharged)

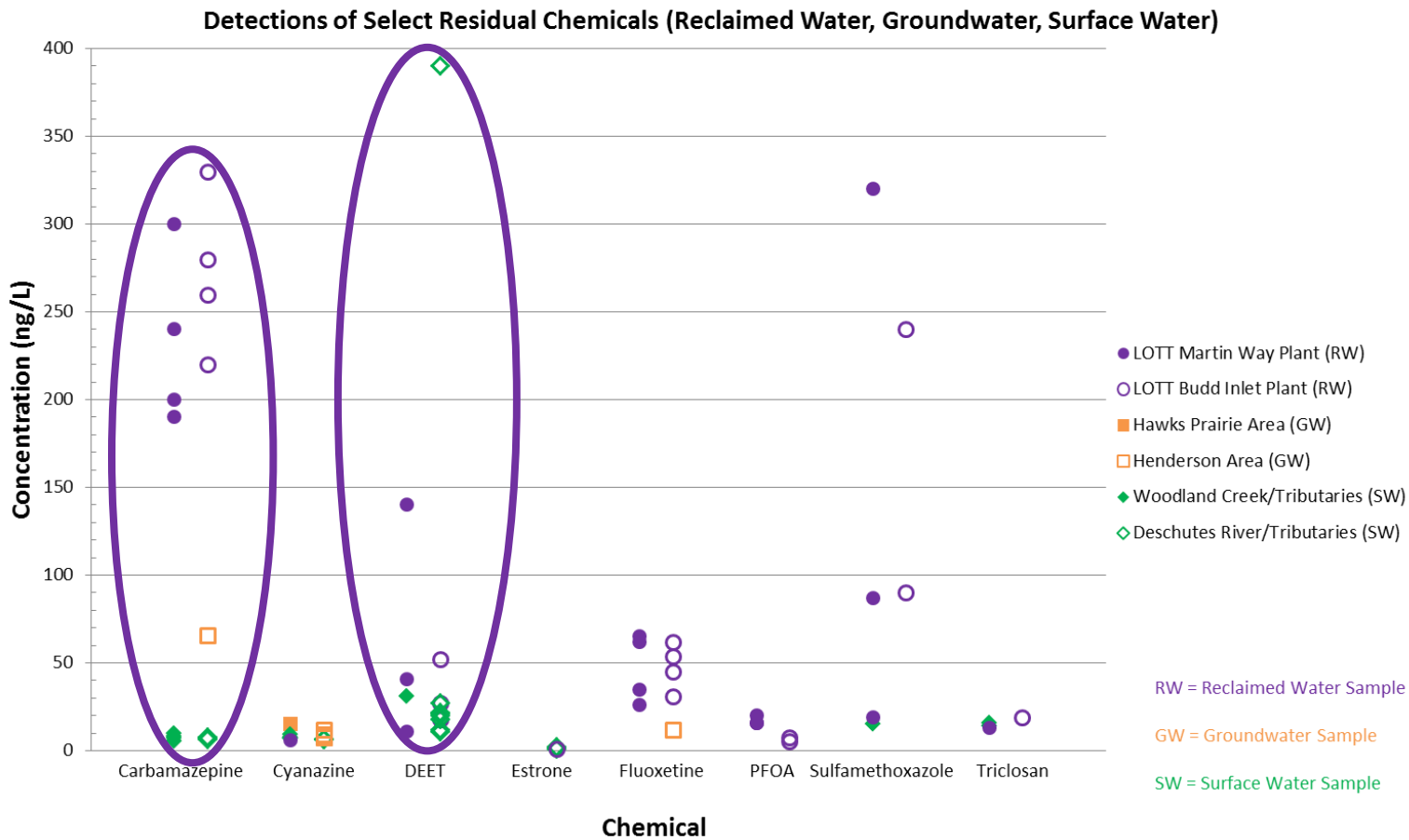
Concentrations of Select Residual Chemicals



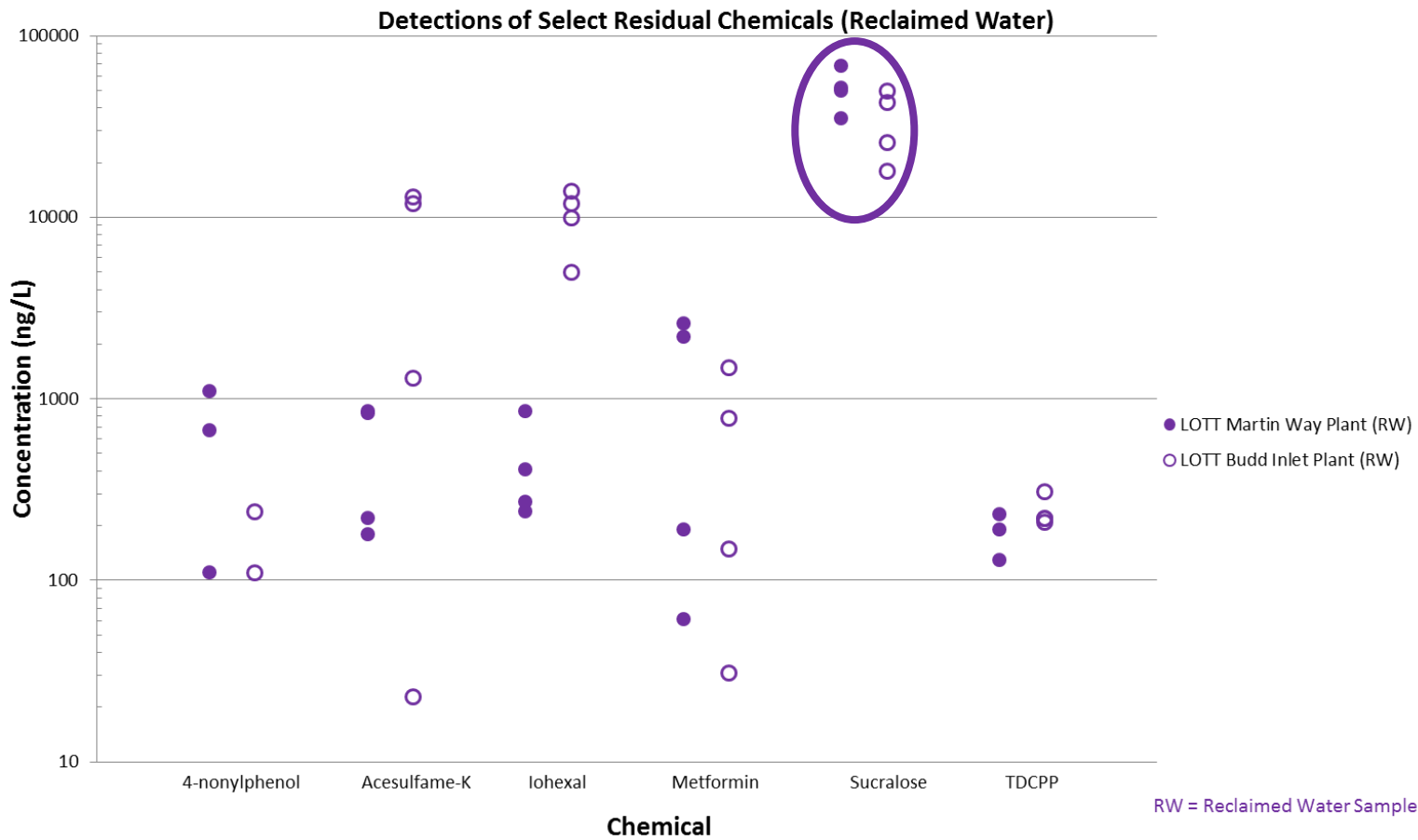
Concentrations of Select Residual Chemicals



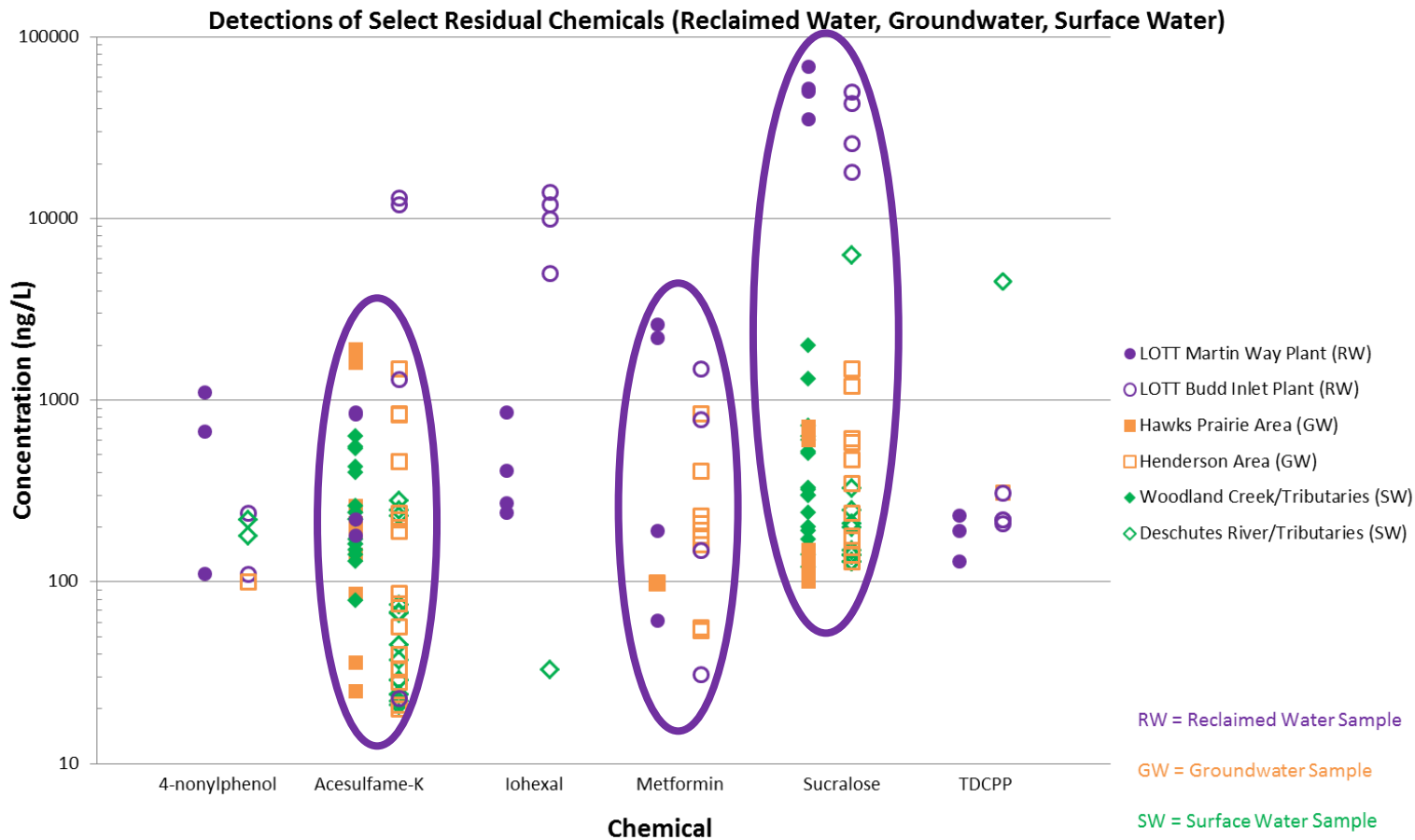
Concentrations of Select Residual Chemicals



Concentrations of Select Residual Chemicals



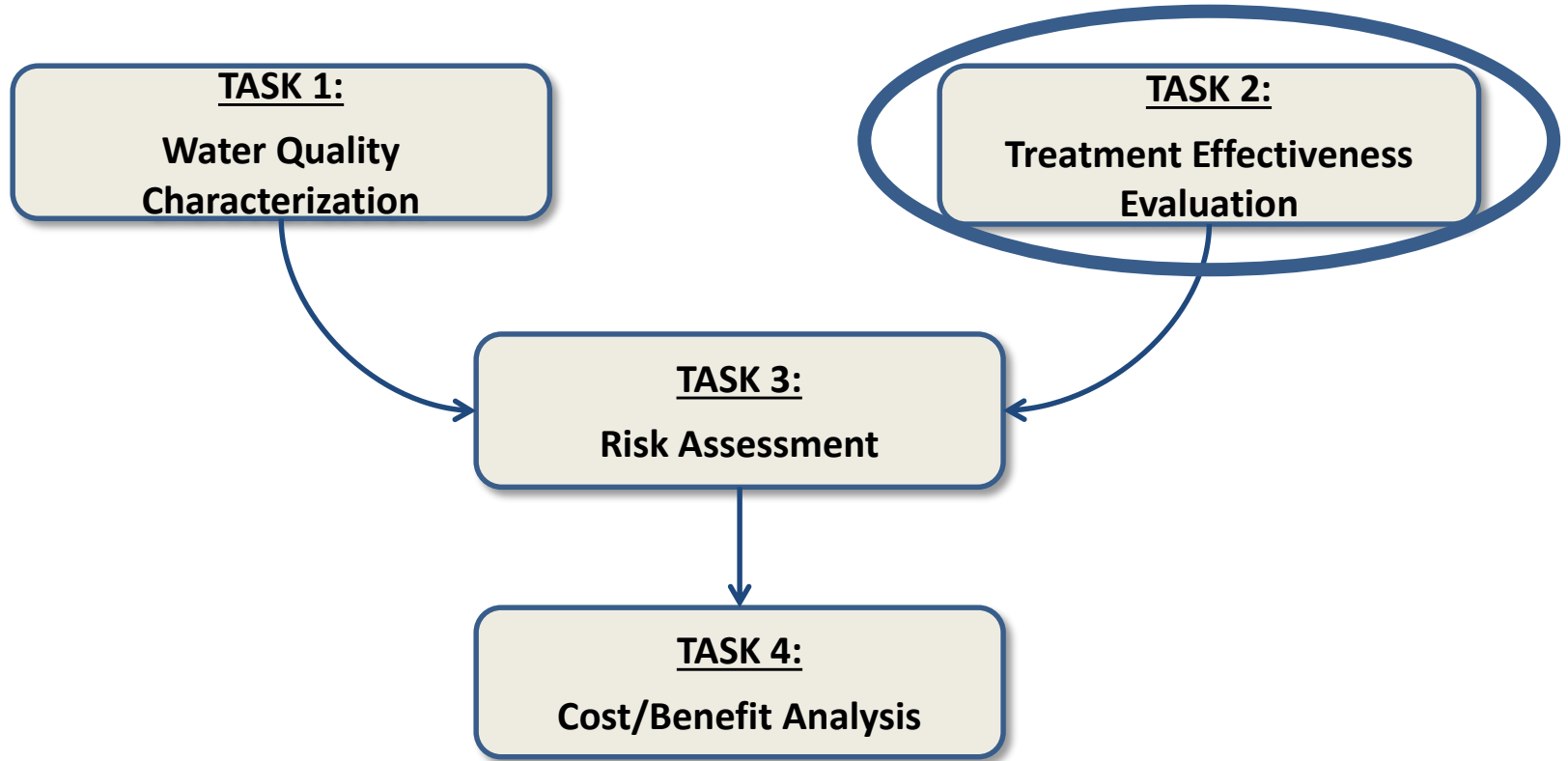
Concentrations of Select Residual Chemicals



Summary of Task 1 Findings

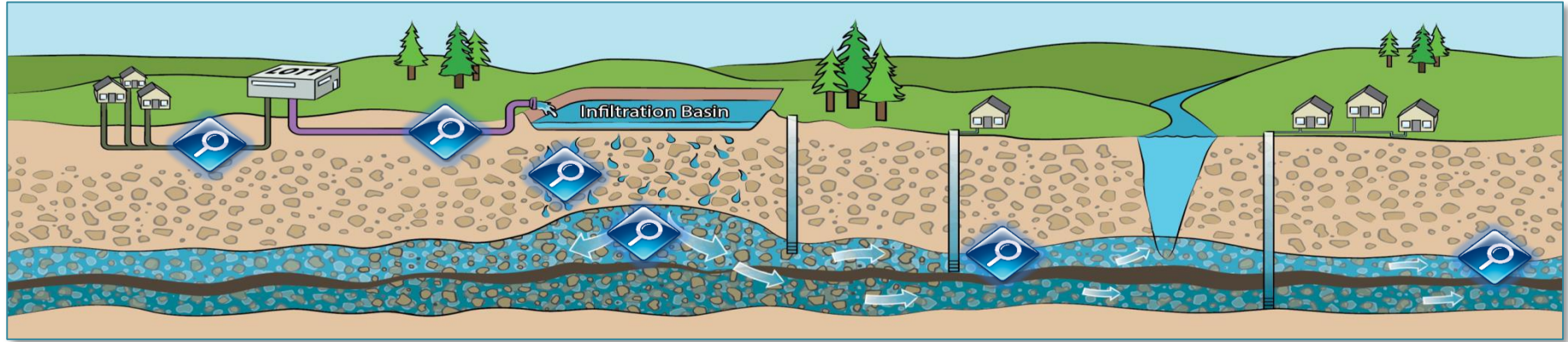
- Findings in all media are similar to what is presented in other studies
- Some residual chemicals are effectively removed by LOTT's treatment processes, while other are fairly recalcitrant
- Some of the residual chemicals detected in reclaimed water are also observed in the environment, including in areas where no reclaimed water use is present

Study Framework



Task 2:

Treatment Effectiveness Evaluation



- Measure water quality at steps within the treatment process (prior to and after infiltration)
- Identify which residual chemicals remain in reclaimed water
- Investigate groundwater movement and chemistry through the use of tracer tests

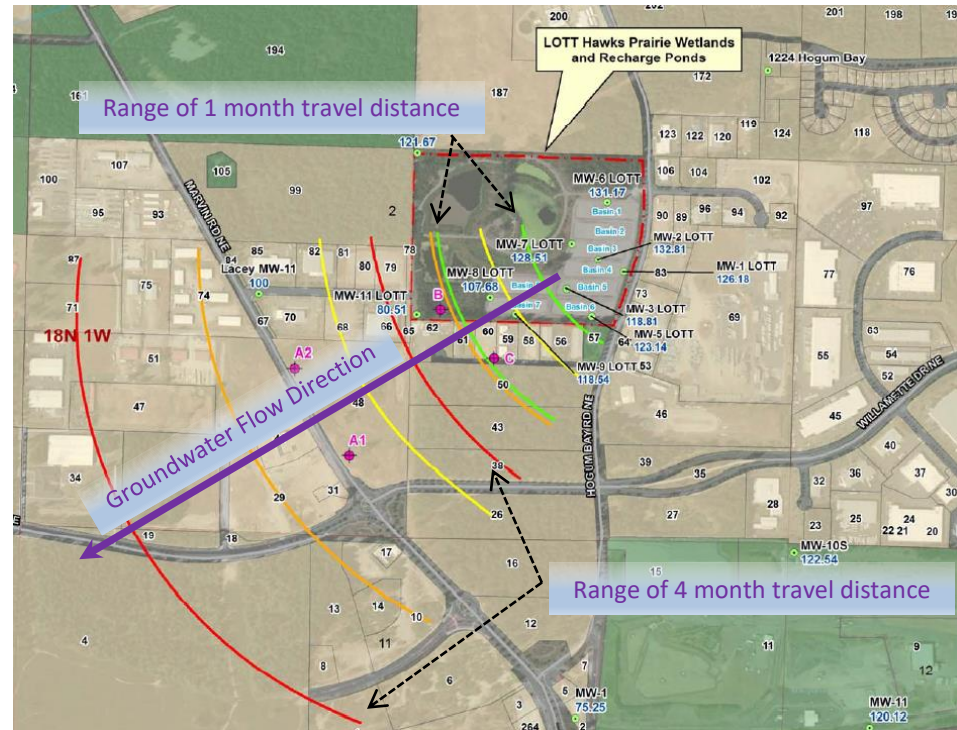
Hawks Prairie: A Living Laboratory



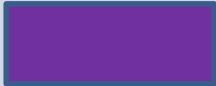

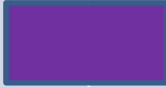
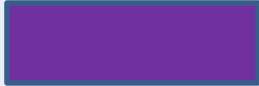
Outline of Task 2 Steps

- Conduct tracer test (physically track reclaimed water movement underground)
- Update computer model
- Characterize reclaimed water flow paths and travel times
- Characterize residual chemical concentrations in groundwater beneath and downgradient from the infiltration basins

Flow Direction and Travel Times (ranges) at Hawks Prairie Site
(based on existing data)



Next Steps

Activity	2019	2020
Task 2: Groundwater Modeling		
Task 3: Risk Assessment (Human Health and Ecological)		
Task 4: Cost / Benefit Analysis		
Reporting Out		

Questions / Discussion

Contact

Jeff Hansen, HDR

360-570-4410

Jeff.Hansen@hdrinc.com

LOTT Project Website: <https://lottcleanwater.org/projects/reclaimed-water-infiltration-study/>