Reclaimed water irrigation water quality impact assessment, Phase 1 Summary of Results

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Introduction

Watershed Protection Department staff collected water samples to enable evaluation of the potential water quality impacts on surface and ground water resources from the irrigation of reclaimed water provided by City of Austin wastewater treatment facilities within the critical water quality zone and floodplain as defined by the City of Austin Land Development Code. Reclaimed water irrigation adjacent to creeks may migrate to shallow groundwater and into creeks through subsurface water flow, may be irrigated directly into creeks during improper spray application, or may load constituents into riparian soils that exceed natural assimilative capacities and thus be transported to creeks during runoff events. The following is a summary of the results of initial sampling from on-site reclaimed water, surface water, ground water and periphyton. Preliminary conclusions based on these initial results are provided at the end of this summary data report.

This project was designed with two phases. Phase one sampling was a one-time evaluation of upstream and downstream conditions relative to on-site reclaimed water and local spring discharge. Sampling for phase two will be determined based on the results of phase one and includes repeated follow-up sampling to illuminate spatial and temporal variability and to allow application of robust statistical analysis methods.

Methods

The field investigation was conducted on October 15, 2014. Physiochemical parameters were collected in the field using a multiprobe water quality meter, and spring and stream discharge was measured with a Marsh McBirney Flowmate. Water samples from reclaimed water sources (irrigation lines and ponds), surface water (streams), groundwater (spring discharge) and periphyton (from rock scrapings) were collected by WPD staff and delivered to the Lower Colorado River Authority laboratory for analysis following City of Austin standard operating procedures.

In the first phase of this study 21 sites within one park and three golf courses with recent application of reclaimed water were sampled (Table 1, Figure 1). Sites included four known springs (10765, 661, 662, and 10769), on-site reclaimed water irrigation source ponds or supply lines (10767, 10775, 10779, and 10768), and upstream/downstream sample sites on creeks (3858/10767, 10773/625, 3879/10778, 10770/10772, and 843/10771).

Table 1. Sites sampled during phase 1.

Location	Site number and name	Purpose
Bartholomew Park	3858 Tannehill Creek @ Berkman Dr	upstream of irrigation
	10766 Tannehill downstream of Bartholomew Spring	downstream of irrigation
	10767 Bartholomew Park Irrigation water	source water for irrigation
	10765 Bartholomew Spring	groundwater spring
Hancock Golf Course	10773 Waller Creek @ 45th	upstream of irrigation
	625 Waller Creek @ 38th	downstream of irrigation
	10775 Hancock Irrigation Water	source water for irrigation
Morris Williams Golf Course	843 Tannehill @ Lovell	upstream of irrigation area (mainstem of Tannehill)
	10771 Tannehill @ MLK	downstream of irrigation area (mainstem of Tannehill)
	10770 Morris Williams Central Trib upstream	upstream of irrigation area (tributary of Tannehill)
	10772 Morris Williams Central Trib downstream	downstream of irrigation area (tributary of Tannehill)
	10768 Morris Williams Irrigation Pond	source water for irrigation
	10769 Moose Lodge Spring	groundwater spring
Jimmy Clay/Roy Kizer Golf Course	10776 Williamson downstream Pleasant Valley	upstream of irrigation
	3879 Williamson Creek at Dove Springs Park	upstream of spring
	661 Roy Kizer Spring	groundwater spring
	10778 Williamson downstream Roy Kizer Spring	downstream of spring
	10779 Roy Kizer Reclaim Water Pond	source water for irrigation
	65 Onion Creek at William Cannon	upstream of irrigation area
	253 Onion Creek at McKinney Falls upper pool	downstream of irrigation area
	662 Driving Range Spring	groundwater spring

Figure 1. City of Austin parks and golf courses and sample locations selected to determine potential for impacts to surface and spring water.

Data for the following parameters were collected in water samples:

Field Parameters
- Conductivity
- Dissolved Oxygen
- Temperature
- pH
- Discharge (flow)

Ions
- Chloride
- Flouride
- Calcium
- Magnesium
- Sodium
- Potassium
- Sulfate
- Calcium Carbonate (Alkalinity)
- Strontium

Nutrients and Organic Carbon
- Nitrogen, Nitrate & Nitrite (as N)
- Ammonia, Total (as N)
- Total Kjeldahl Nitrogen (as N)
- Phosphorus, Total (as P)
- Orthophosphorus Total (as P)
- Total Organic Carbon (TOC)

Stable Isotopes
- Nitrogen-15/Nitrogen-14 Ratio
- Oxygen-18/Oxygen-16 Ratio

In addition to water samples, periphyton scrapings from rocks (epilithon) were collected from randomly selected rocks within the riffles upstream and downstream of each irrigation site. Pursuant to City of Austin Standard Operating Procedures, rocks were collected from undisturbed areas in the riffle before other sampling had occurred. Rocks chosen were relatively flat to ensure a consistent sample area. An area of 47 cm^2 was scraped from each rock and placed into a shallow collecting pan. Each rock was rinsed with deionized water to flush epilithon from the rock. Material from nine rocks in each riffle was composited in the collection pan and then placed into one darkened sample bottle and one sample bottle with H_2SO_4 for preservation. Samples were analyzed for chlorophyll *a* (opaque bottle), total organic carbon, total phosphorus, ammonia, nitrate plus nitrite, and Total Kjeldahl Nitrogen (acidified bottle).

Results and Discussion

The only site that was dry at the time of the investigation was Williamson at Pleasant Valley (site 10776), which was intended to represent upstream conditions for the segment of Williamson creek at Roy Kizer Golf Course. Williamson Creek surface flow at the time of this investigation originated near the Roy Kizer Golf Course, but an accurate total stream discharge was difficult to measure due to a portion of the discharge flowing through the cobble and gravel alluvial substrate. The next available site with measurable flow to represent upstream conditions was Williamson at Dove Springs (site 3879). Although Williamson at Dove Springs was used to represent upstream conditions for Williamson Creek, it may already have been impacted by migration of reclaimed water effluent from the golf course.

<u>Reclaimed Water Characterization</u>

Reclaimed water holding ponds were sampled at the Morris Williams and Roy Kizer golf courses, and samples were collected directly from reclaimed water irrigation supply lines at Hancock Golf Course and Bartholomew Park (Table 2). Concentrations of nutrients are reduced in the ponds relative to the direct irrigation supply line samples. Ion concentrations in the Roy Kizer storage pond are anomalous with respect to the other samples and long-term Walnut Creek WWTP averages.

Table 2. Results (mg/L) from reclaimed water supplies versus average (2007-2009) Walnut Creek Wastewater Treatment Plant effluent. Total nitrogen is calculated from constituents, and cannot be completely estimated in Walnut Creek WWTP effluent because organic nitrogen data is missing.

Parameter	Bartholo-mew	Hancock	Morris Williams Pond	Roy Kizer Pond	Walnut Creek WWTP Effluent	
					average	stdev
Alkalinity as CaCO3	31.2	38.2	33.4	110	35.33	23.43
Ammonia as N	0.812	0.774	0.043	0.0436	0.28	0.62
Calcium	45.8	45	42.8	35.7	38.23	6.35
Chloride	113	113	119	108	90.83	18.09
Conductivity	1082	1137	1058	827.6	.	.
Dissolved Oxygen	7.83	5.14	16.67	13.49	7.59	0.69
Fluoride	1.75	1.78	1.59	1.32	1.93	0.63
Magnesium	28	26.9	29.3	26.7	17.29	1.43
Nitrate+Nitrite as N	25.5	28.5	14.9	16	20.42	3.76
Orthophosphorus as P	4.51	4.71	0.631	1.08	4.45	1.18
pH	6.83	6.48	9.98	9.75	6.70	0.34
Phosphorus as P	4.62	4.53	1.36	1.44	4.49	1.17
Potassium	15	14.3	15.9	15.7	.	.
Sodium	117	112	122	82.5	76.82	9.19
Strontium	0.265	0.258	0.248	0.179	0.28	.
Sulfate	180	191	181	63.7	90.75	20.42
Total Kjeldahl Nitrogen as N	1.28	0.882	1.68	1.98	.	.
Total Nitrogen as N	26.78	29.38	16.58	17.98	>20.70	.

Discharge

Stream discharge was present at the upstream end of the central tributary on the Morris Williams Golf Course. However, due to the low flow (estimated <0.001 ft^3/s) it was not measured. Flow at all other sites was present during the sample event (Figure 2). Although some stream reaches were gaining flow while others were losing flow, the available baseflow enabled upstream/downstream comparisons. Bank seeps were observed in gaining stream reaches at Morris Williams Golf Course. Direct discharge of reclaimed water was observed to a biofiltration stormwater control and thence to Tannehill Creek at Bartholomew Park. The losing nature of some of these stream reaches may be due to subsurface flow thru alluvial substrate.

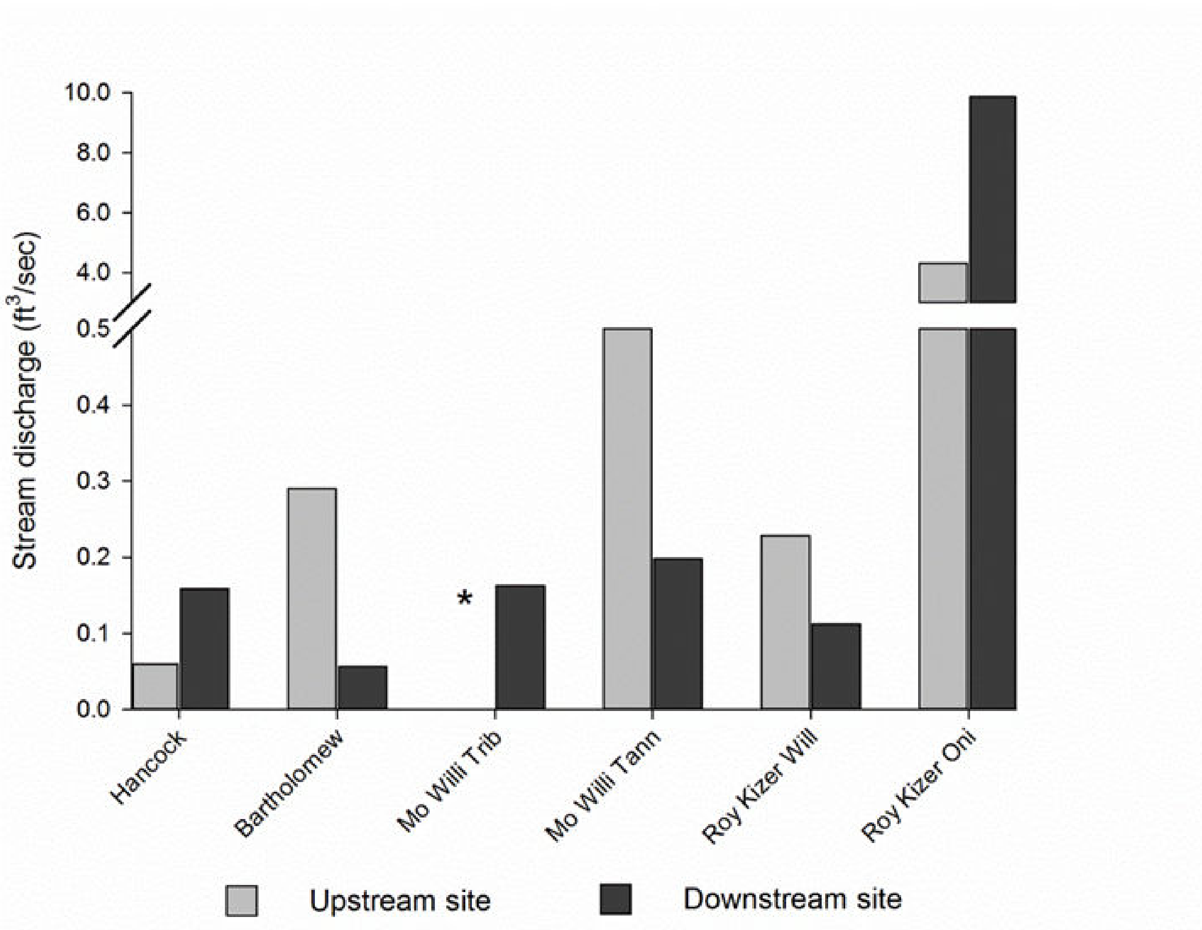

Figure 2. Stream discharge at upstream and downstream sample sites. See maps in Figure 1 for spatial orientation of upstream and downstream study sites. *Upstream site at Morris Williams Central Tributary was flowing, but was <0.001 cfs.

Conductivity

Conductivity was higher at downstream sites compared to upstream sites in 4 of 6 pairs (Figure 3). The difference in conductivity was larger between the upstream/downstream sites of the three creeks with low flow on bedrock stream substrate (i.e. Bartholomew, Morris Williams Tributary, Roy Kizer Williamson). Conductivity differences between upstream/downstream pairs were minor on larger creeks (i.e. Hancock Waller and Roy Kizer Onion) where higher baseflow could dilute the influence of reclaimed water or baseflow was largely subsurface thru alluvial substrates.

Average conductivity of upstream sites was 450 µS/cm (range 279 – 841 µS/cm)while the average conductivity of downstream sites was 565 µS/cm, which is an increase of 25%. Elevation of the specific conductance in the baseflow of a stream would be expected if there were contributions from reclaimed wastewater since reclaimed water samples indicated a much higher average conductivity (1,026 µS/cm).

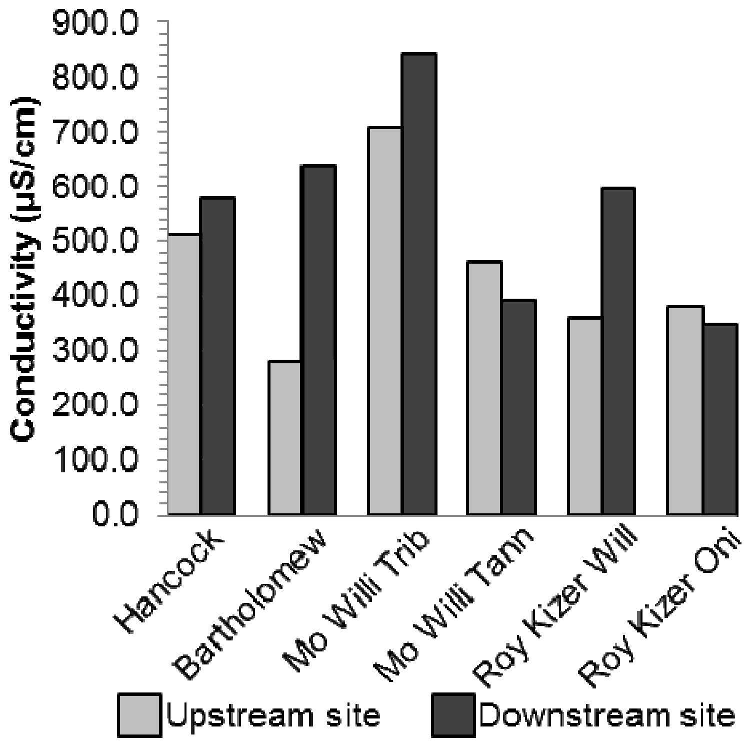

Figure 3. Conductivity values at upstream and downstream sample sites.

Chloride and Fluoride

Chloride and fluoride can be used to detect influence of municipal treated water or wastewater on surface and ground water in Austin.

A comparison of fluoride concentrations from upstream and downstream sites in the study area shows that most (4/6) sites have higher concentration in downstream samples compared to upstream samples (Figure 4A). The average fluoride concentration in reclaimed water was 1.61 mg/L, and Austin Water maintains fluoride concentrations in finished drinking water with a control range of 0.6 to 0.8 mg/L. As would be expected, differences are less evident in stream segments on the mainstem of large creeks such as Waller and Onion whose higher baseflow and urban influences obscure or dilute potential. Average fluoride concentration for all upstream sites was 0.25 mg/L while the average concentration for all downstream sites was 0.28 mg/L.

More prominent differences were observed in the comparison of chloride results from upstream to downstream relative to fluoride concentrations. Sample results show that most sites (5/6) have a higher concentration in downstream samples (Figure 4B). Average chloride concentration in reclaimed water was 113 mg/L. Average chloride concentration for all upstream sites was 20 mg/L while average concentration for all downstream sites was 42 mg/L.

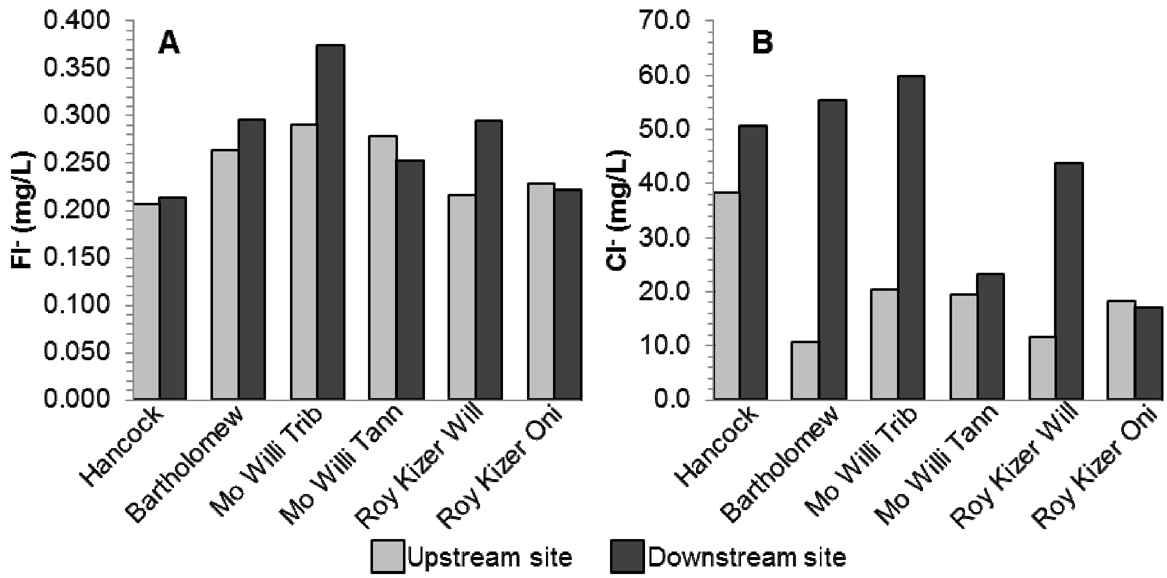

Figure 4. Fluoride (A) and chloride (B) concentrations at upstream and downstream sample sites.

Because chloride and conductivity are generally conservative in surface water, a simple mass balance calculation utilizing the concentrations of upstream, downstream and reclaimed water sites can be made to estimate the maximum potential ratio of reclaimed water exfiltrating from soils into creeks relative to upstream flow (Table 3). This calculation assumes that the difference between upstream and downstream concentrations would only be a result of reclaimed water addition to the adjacent creek. This mass balance analysis suggests the highest potential influence of reclaimed water on adjacent creeks occurs in Bartholomew Park, the Central Tributary to Tannehill in Morris Williams Golf Course, and in Williamson Creek adjacent to Jimmy Clay/Roy Kizer Golf Course.

Table 3. Ratio of the maximum potential reclaimed water exfiltration to streams relative to upstream surface water discharge estimated by simple mass balance. Negative ratios occur when downstream concentrations exceed upstream concentrations.

Parameter	Bartholomew	Hancock	MorrisWilliams (Tannehill mainstem)	MorrisWilliams (Tannehill Central Tributary)	Onion	Williamson
Conductivity	0.81	0.12	-0.10	0.61	-0.07	1.02
Chloride	0.78	0.20	0.04	0.67	-0.01	0.50

Additional Ions

In addition to physiochemical and chloride/fluoride concentrations, a suite of cation and anion parameters were evaluated to determine if surface water impacts are occurring within the study area (Figure 5A-F). As shown in Figure 5, most of the downstream sites were higher in concentration than the upstream sites for all ions. Of the total 36 upstream/downstream comparisons, the downstream site was higher in ion concentration than the upstream site in 28 instances. Although the Hancock sites did not show much difference, some increased downstream concentrations were evident. For all six ions compared at Bartholomew Park, ion concentration of downstream sites increased between 2-4 times that of upstream sites. Of note, the central tributary of Morris Williams Golf Course (Figure 5F, Mo Willi Trib) saw an eight-fold increase in sulfate.

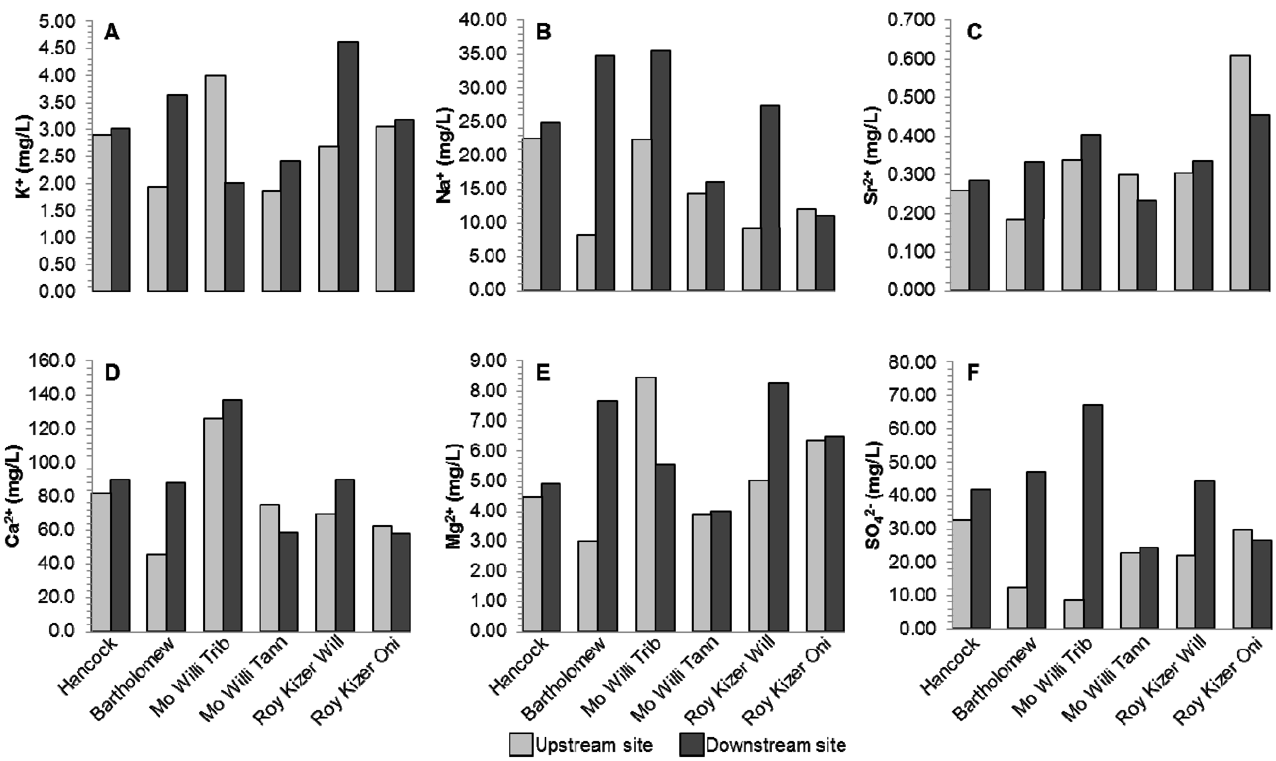

Figure 5. Potassium (A), sodium (B), strontium (C), calcium (D), magnesium (E), and sulfate (F) concentrations at upstream and downstream sample sites.

Analysis of groundwater (spring discharge) indicates similar results to surface water. Characterization of groundwater typically includes examining the cation and anion concentrations to determined hydrochemical facies of the groundwater system. The standard ions used are Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, and Cl^-. The trilinear graph or "piper plot" is the standard method for presenting the cation and anion data. Each apex of a triangle represents 100% of one or two ion constituents, with the cations represented at the lower left triangle and anions at the lower right triangle (Figure 6). The diamond-shape area between the two triangles is used to project a point that represents both the cation and anion concentrations. The advantage of the piper diagram is that a large number of samples with multiple parameters can be plotted to reveal trends with minimal confusion. The effects of mixing water from two different sources can become apparent. The mixing of two different waters will result in a plot in which unimpacted waters will be separated from pollution sources, and the impacted waters will form an intermediate line in between.

The ion data for the reclaimed water results is shown in the piper plot (Figure 6). Reclaimed water (from irrigation lines and ponds) is clearly distinct in its characterization within the plot on the right hand sides (pink squares) while the upstream, or unimpacted sites (open triangles) are clustered on the left hand side. The downstream sites (grey triangles) migrate in the direction of the reclaimed water characterization. The linear drift in the ion data towards the ion composition measured for reclaimed water indicates the mixing of sodium, chloride and sulfate enriched reclaimed irrigation water with both the background groundwater and surface water.

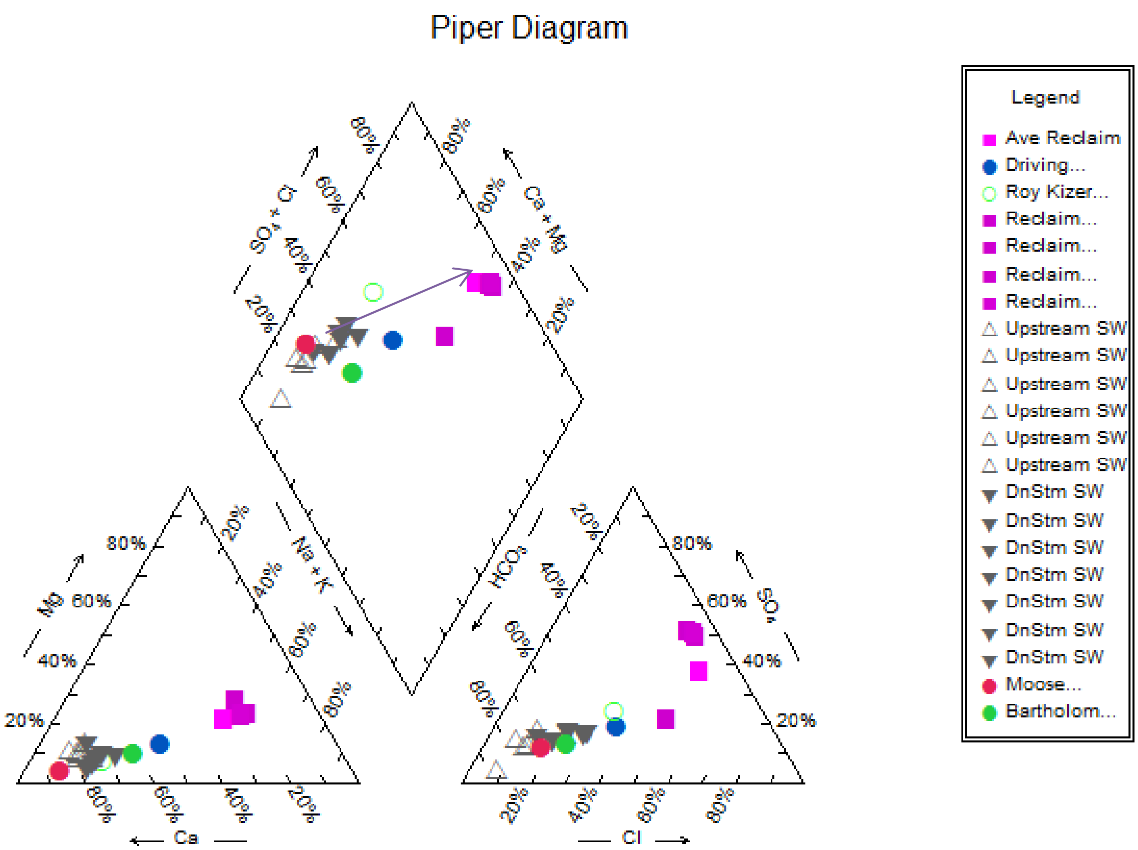

Figure 6: Piper diagram of major cation and anion data.

<u>Nutrients</u>
Excess nutrients in surface water can result in nuisance algal blooms that cause swings in dissolved oxygen concentrations, aquatic life community imbalance, odor problems and fish kills (Wharfe et al. 1984; Biggs 1985; Biggs and Price 1987; Welch et al. 1988; Quinn and Gilliland 1989; Quinn and Hickey 1990). Nutrient concentrations were higher at the majority of the downstream sites compared to the upstream sites (Figure 7A-F), especially as shown by nitrate/nitrite concentrations (Figure 7D). The increase in nutrient concentrations is most evident at Bartholomew Park and at Morris Williams Golf Course. Of note, the nitrate/nitrite concentration at the downstream site was 55 times higher than the

upstream site at both Bartholomew Park and Williamson Creek sites associated with Roy Kizer Golf Course. The average nitrate/nitrite concentration at upstream sites was 0.32 mg/L while the average downstream concentration was 1.15mg/L (total range 0.02 – 2.00 mg/L). Similarly, an increase in phosphorus (both orthophosphorus and total phosphorus) concentration is seen between upstream and downstream at four of the six monitoring sites (Figure 7E). Increases in nutrients at Morris Williams Golf Course and Bartholomew park were particularly noticeable. All of the nutrient parameters (TN, TKN, NH3, NO2+NO3, TP and OP) evaluated on Morris Williams Golf Course Tannehill sites (see Mo Willi Tann below), were between two to twenty-five times higher at the downstream sites than at the upstream sites. All nutrient parameters were higher at the downstream sites of Bartholomew Park as well.

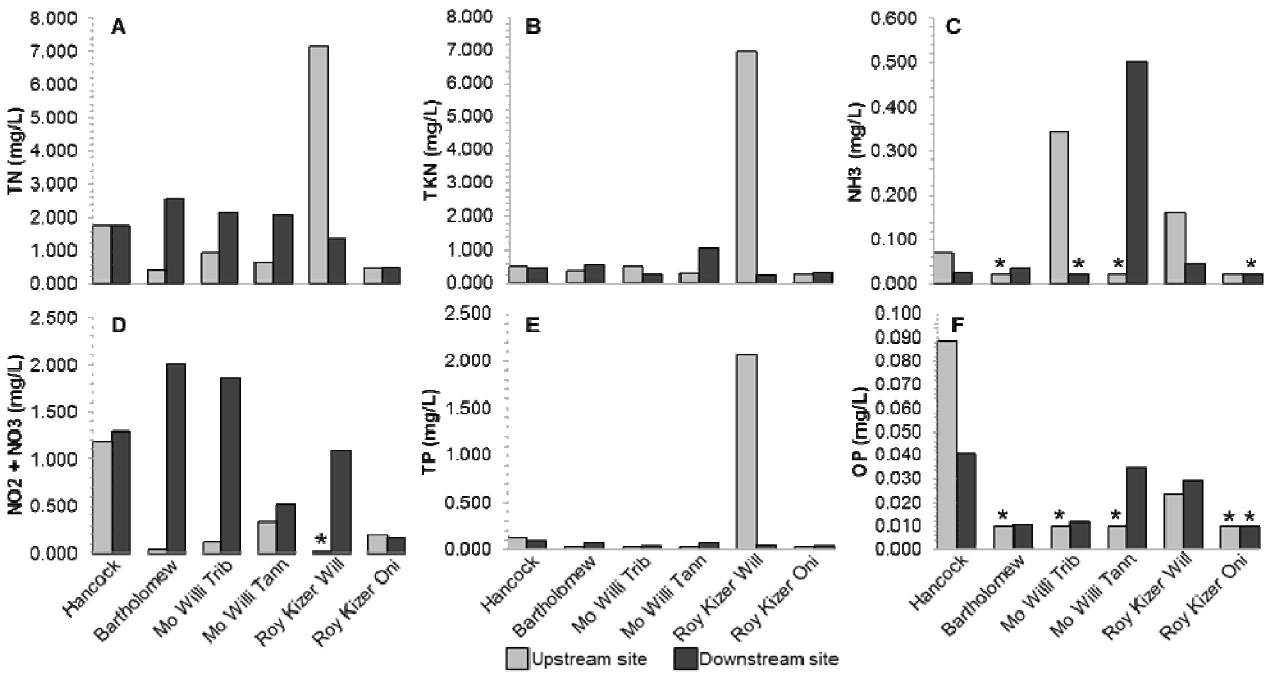

Figure 7. Total nitrogen (A), total kjeldahl nitrogen (B), ammonia (C), nitrate and nitrite (D), total phosphorus (E), and orthophosphate (F) at upstream and downstream sample sites. * indicates sample concentrations were below detection limits.

The total phosphorus concentration at the upstream site on Williamson Creek at the Roy Kizer Golf Course was 2.00 mg/L, two orders of magnitude greater than the background concentrations of about 0.02 mg/L. Although Williamson Creek was dry just upstream of the Roy Kizer Golf Course (site 10776), the creek begins to flow as it winds around the golf course (site 3879). The observed elevated total phosphorus concentration recorded at Williamson Creek above Roy Kizer Kizer Spring may be a result of reclaimed water contribution to the shallow groundwater seepage that creates surface baseflow in this reach.

Benthic Algae

Chlorophyll *a* is commonly used to determine the algal biomass of a system.
Carbon:Nitrogen:Phosphorus stoichiometry in algal cells has been shown to respond to increases in nutrient loads. An increased load of nitrogen or phosphorus leads to lower C:N or C:P ratios in periphyton communities (Hillebrand and Kahlert 2001; Hillebrand and Kahlert 2002; Stelzer and Lamberti 2001; Frost and Elser 2002; Bowman et al. 2005). The increased amounts of nitrogen or phosphorus in the algal

cells can lead to an increase in the algal growth rates (Rhee 1973; Droop 1974). This may allow benthic algal biomass to increase more rapidly in nutrient enriched water.

Benthic algae results for the C:P ratios and chlorophyll *a* content of samples collected upstream and downstream of irrigation sites were calculated on a consistent spatial scale (Table 4). Results for the benthic algae samples collected in the tributary to Tannehill Creek downstream of the Morris Williams Golf Course are not shown because a lack of rock substrate in the upstream site did not allow for benthic algae collection and thus there is no data available for comparison.
Table 4: Benthic algae chlorophyll *a* and carbon to phosphorus (C:P) ratios collected upstream and downstream of each reclaim irrigation site.

Site	Benthic Chlorophyll a (mg/m^2)		Benthic C:P Ratio	
	Upstream	Downstream	Upstream	Downstream
Bartholomew	35.40	56.60	11.1	10.4
Morris Williams:Tannehill mainstem	79.40	88.90	15.3	7.8
Hancock: Waller	26.10	65.00	8.0	9.8
Clay/Kizer: Onion	14.10	8.30	17.7	6.1
Clay/Kizer: Williamson	9.20	41.40	26.3	9.8

Benthic chlorophyll *a* (mg/m^2) increased from upstream to downstream at four out of five irrigation sites (Figure 8). Not enough data points exist yet to perform a statistical analysis with strong power to ensure statistical inferences would be accurate; however, the increasing pattern in the benthic chlorophyll *a* suggest an increase in nutrient loading to the creek at the potentially irrigation-influenced downstream sites. In addition, the trophic status as proposed by Dodds et al. (1998) and accepted by the US Environmental Protection Agency (2001) may have shifted from oligotrophic (< 20 mg/m^2 chlorophyll *a*) to mesotrophic (20-70 mg/m^2 chlorophyll *a*) on Williamson Creek upstream to downstream of the Clay/Kizer irrigation area. More sample events are needed at the study reaches before trophic status can be definitively determined.

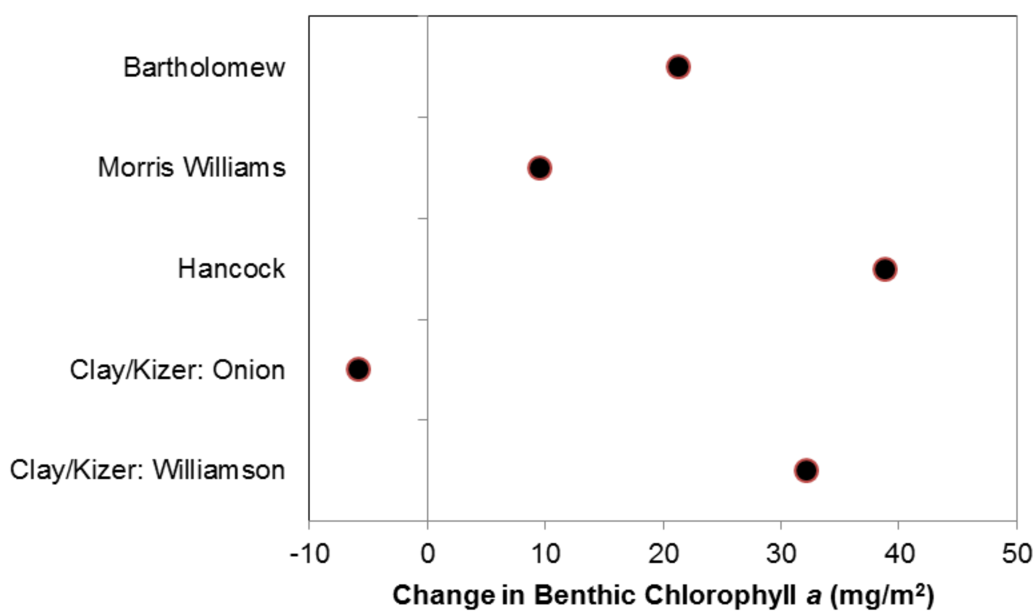

Figure 8: Change in benthic algae chlorophyll *a* (mg/m^2) from upstream to downstream at each site.

Benthic C:P ratios decreased from upstream to downstream at four out of five irrigation sites (Figure 9). Not enough data points exist yet to perform a statistical analysis with strong power to ensure statistical inferences would be accurate; however, the decreasing pattern in the benthic C:P ratios suggest an increase in nutrient load to the creek at the downstream sites.

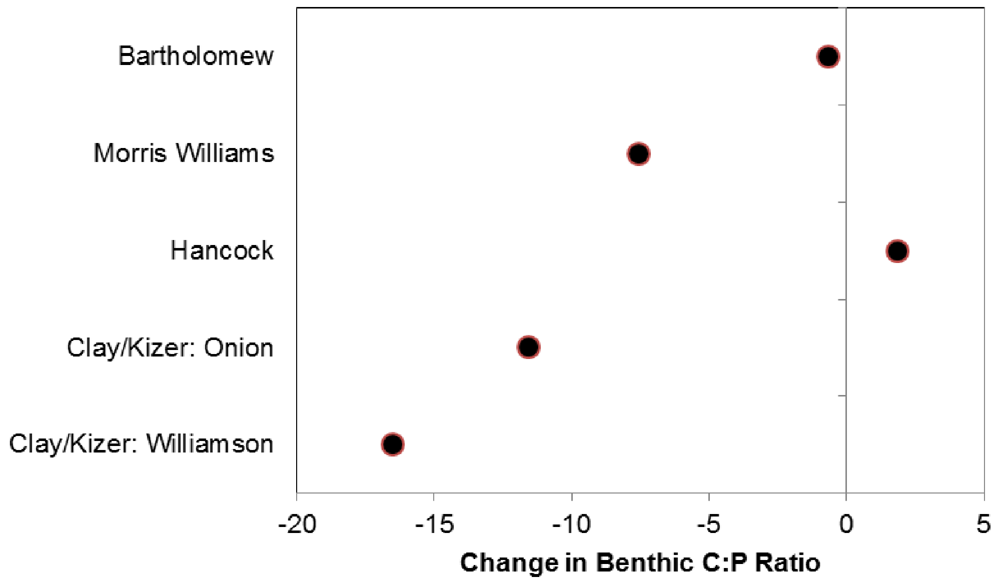

Figure 9: The change in benthic algae carbon to phosphorus (C:P) ratios from upstream to downstream at each reclaim irrigation site.

Nitrogen Isotopes

Lab analysis of the stable nitrogen and oxygen isotope ratios of nitrate collected during the initial October 25, 2014, sampling event revealed that all sites with sufficient nitrate for isotope analysis plotted in the biogenic range, suggesting that the source of nitrogen was manure or wastewater (Figure 10). There was no indication that the nitrogen was originating from precipitation or fertilizer application. Both upstream and downstream sites on Waller plotted in the biogenic range, possibly indicating leaking wastewater infrastructure upstream of the Hancock Golf Course. The inconsistent relationships between the irrigation water sources and the receiving water samples are intriguing, and suggest that differential nitrification and denitrification processes may be occurring.

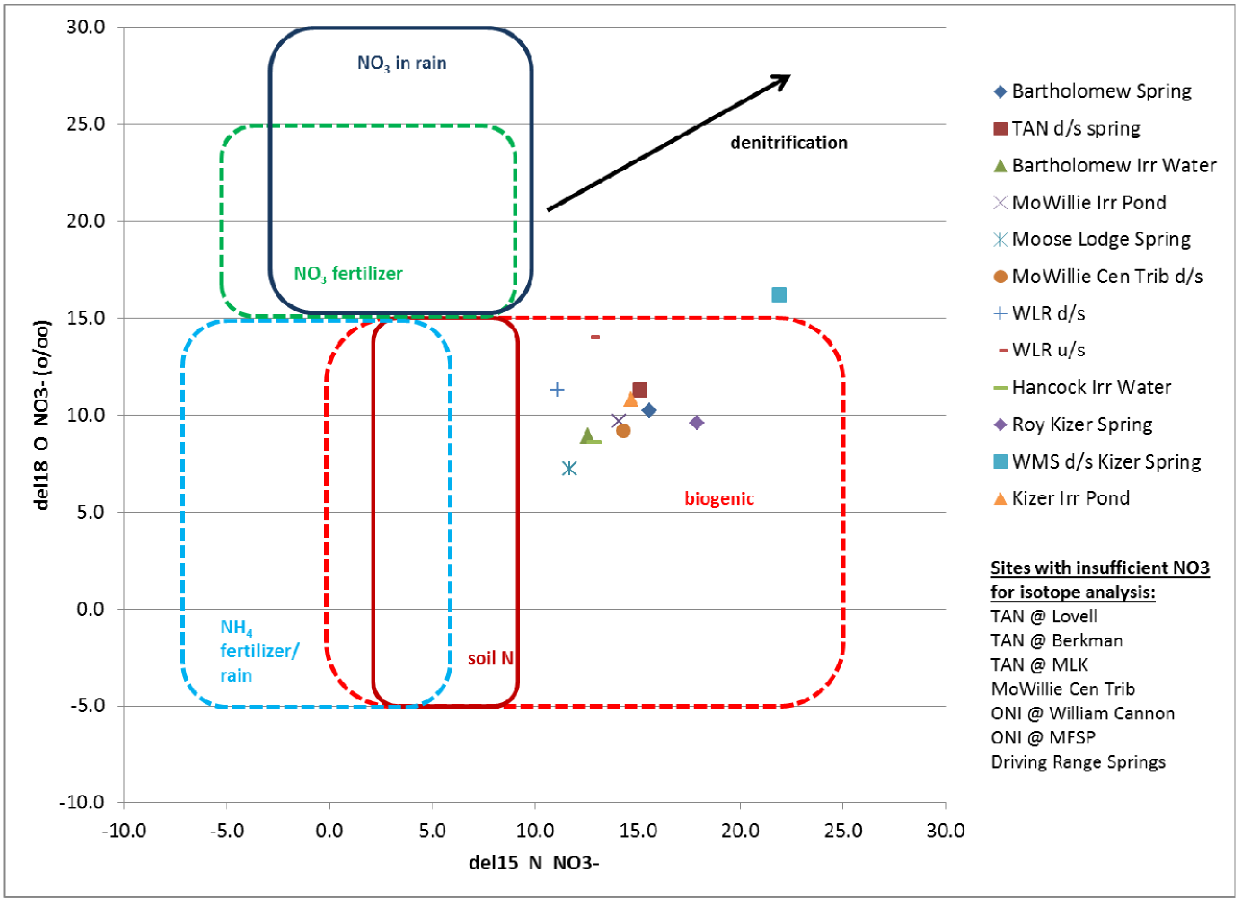

Figure 10. Nitrogen/Oxygen stable isotope ratio plot for study sites.
Source boundaries adapted from Kendall 1998.

Conclusions

As phase one of a two phase study, surface water and groundwater samples were collected on October 15, 2014, at sites upstream and downstream of four locations utilizing City of Austin reclaimed water for irrigation in close proximity to creeks. Samples were analyzed for physiochemical parameters, ions, nutrients, and nitrate isotopes. Benthic algal scrapings were analyzed for area-adjusted algal biomass and nutrient to carbon ratios. Initial analysis of the phase one results indicates:

- Reclaimed water chemical composition changed when the reclaimed water was stored in open holding ponds relative to composition in distribution pipes.

- Conductivity was higher in 4 out of 6 sites downstream of reclaimed water irrigation areas. Average conductivity of upstream surface water sites was 450 µS/cm, and average conductivity of downstream surface water sites was 565 µS/cm.
- Chloride (5/6) and fluoride (4/6) were generally higher in sites downstream of reclaimed water irrigation areas. Average chloride concentrations for upstream surface water sites was 20 mg/L, and average chloride concentrations for downstream surface water sites was 42 mg/L.

- Mass balance of chloride and conductivity, which are conservative in Austin streams, suggests the highest potential influence of reclaimed water on adjacent creeks occurs in Bartholomew Park, the central tributary to Tannehill Branch in Morris Williams Golf Course, and in Williamson Creek adjacent to Jimmy Clay/Roy Kizer Golf Course.
- Ion concentrations generally increase at surface water sites downstream of reclaimed water irrigation.

- Ion composition at springs adjacent to reclaimed water irrigation locations and downstream surface water sites are migrating towards a composition more similar to reclaimed water relative to upstream surface water composition.

- Increased nutrients, especially nitrate plus nitrite, are generally observed in downstream samples. Total nitrogen and total phosphorus were higher in 4 out of 6 sites.

- Nitrogen and oxygen isotopes of nitrate for all sites with sufficient nitrate for analysis indicated that nitrogen was originating from biogenic (manure or wastewater) sources. Nitrogen in Waller Creek upstream of Hancock Golf Course also yielded a biogenic signature.
- Benthic chlorophyll *a* concentrations and C:P ratios suggest an increased loading of nutrients downstream of irrigations sites. Benthic chlorophyll *a* concentrations downstream of the Clay/Kizer Golf Course might be indicative of a change in trophic status of Williamson Creek.

Acknowledgements

This initial sampling event was completed with the assistance of multiple City of Austin Parks and Recreation Department staff, who facilitated access to the park and golf course locations. Additionally, Dan Pedersen with Austin Water provided background information on the use of reclaimed water at these locations, and provided reclaimed water sampling information. Watershed Protection Department expresses thanks to these individuals for assisting with this project.

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