Tracing the Evolution of Water Quality in Waller Creek on the UT-Austin Campus

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It is well documented that urbanization has an adverse affect on water quality, yet there is still need for a detailed understanding and quantification of the anthropogenic sources and processes responsible for such effects. To address this need, a geochemical evaluation of Waller Creek throughout the UT Ausin campus was conducted to determine the spatial variability of water compositions during both base-flow and storm conditions and to trace source water inputs that influence creek-water compositions. Six sites within Waller Creek and seven sites of discrete discharge from pipes into the creek were sampled monthly from May to November 2013 as well as during a storm event. Creek and pipe water samples, along with Austin municipal water, UT Austin swimming pool water, and rainwater were analyzed for major and minor elemental concentrations. Source waters are assessed using the observed changes in these waters through space and time and principal component analysis. We identify four source waters, or "end-members" that affect Waller Creek water compositions: storm runoff, municipal water, wastewater, and swimming pool water. The storm runoff end-member has low elemental concentrations relative to the creek and the pipes that discharge during base-flow, except for Al, Pb, Zn, Cr, and Fe, which occur in higher concentrations in storm runoff and creek flow. Austin municipal water is distinguished by high pH values (~9.5) and F and Cl (~0.5 ppm and ~40 ppm, respectively) concentrations, as well as low alkalinity relative to natural stream water in a limestone terrain such as Waller Creek. Wastewater has high concentrations of NO_3 (up to 120 ppm), Na (40 to 50 ppm), and Cl (70 to 80 ppm), and elevated concentrations of some trace elements (e.g., B, Ba, and Br). Swimming pool water has concentrations of Cl and Na substantially higher than a natural freshwater system (>500 ppm). The impact of these anthropogenic sources on Waller Creek water compositions is concerning. Wastewater input poses a risk to public health and can drive excessive nutrient loading to the

ecosystem. High salt concentrations in swimming pool water and elevated metal concentrations in storm runoff can also induce adverse effects on ecosystems located on and downstream from the UT Austin campus. These results are consistent with a previous study that demonstrated that Waller Creek water compositions are influenced by municipal, and possibly wastewater. This study, however, is novel in i) analyzing discrete anthropogenic inputs (ie. pipe discharge) to Waller Creek, and ii) providing evidence that swimming pool discharge is a major source of creek water constituents.

1. Introduction

As urban development increases in Austin, there is a need to implement infrastructure that will prevent degradation of water quality in its watersheds. It has been well-documented by previous studies that urbanized streams can be heavily influenced by several anthropogenic factors: discrete points of discharge such as pipes, leaky utility lines carrying treated municipal water or wastewater, increased storm water runoff from impervious cover, atmospheric deposition of contaminants (e.g. from engine combustion), garbage, animal waste, artificial stream channels, narrow riparian zones, and instability and steepness of banks from increased erosion.[1] A case study for Austin found that urbanized streams can be artificially recharged by municipal water from irrigation and utility lines, and can range from <1 percent to up to nearly 100 percent of total recharge.[2] These anthropogenic influences can have a detrimental impact on water quality and pose public health risks and adverse effects on ecosystems.

The Waller Creek headwaters are in North Austin and flow southward through UT Austin campus, downtown Austin, and then discharge into Lady Bird Lake. Since 2013, the creek has been undergoing a redevelopment project with several goals including increased recreational use on the creek and flood control to allow development on acres that are currently unusable.[3] The plan requires serious modification to Waller Creek, which may include artificial stream channels and narrow or non-existent riparian zones, and could be detrimental to water quality. If the project is successful, it will make Waller Creek a more central feature of Austin as well as the The University of Texas at Austin campus.

Currently, Waller Creek overall water quality is rated as marginal[4] and has been identified as unsuitable for human recreational use due to characteristics that are indicative of anthropogenic influence.[5] The Waller Creek watershed is the most urbanized in Austin with ninety percent impervious cover, and a previous study found that the major constituent of the creek base-flow is municipal water.[3, 6] Although past studies on Waller Creek have found that urbanization has detrimental impacts on water quality, none have sought to identify discrete sources or processes that control creek water compositions. A substantial portion of Waller Creek overlaps with the densely populated and urbanized UT Austin campus, and therefore UT Austin has the potential to be a significant influence on Waller Creek water quality. Because The University of Texas at Austin is committed to sustainability, its impact on Waller Creek must be addressed.

To determine the University's impact on water quality in Waller Creek, this study sought to: i) evaluate the geochemical evolution of Waller Creek from the point it enters to the point it exits campus, ii) determine the spatial variability of water compositions during base-flow and storm conditions, and iii) determine the sources and/or processes that dominantly influence creek-water composition.

2. Methods

Reconnaissance survey was conducted

to delineate and describe possible anthropogenic tributaries (i.e., pipe discharge) to the creek. Following this survey, 6 anthropogenic tributaries and 6 sites along the creek were monitored from May through November 2013 (Figure 1). Monthly water samples were collected during base-flow conditions, and a storm was sampled in four discrete events: pre-storm base-flow and the rising limb, peak, and falling limb of the storm hydrograph. Austin municipal water, UT Austin swimming pool water, and rainwater were also sampled. Samples were collected in polypropylene bottles for anion and cation analysis, and amber glass vials with zero headspace for alkalinity analyses. All bottles were pre-cleaned over a multi-day period using micro-soap, distilled water, and ultrapure water rinses. A subset of bottles were additionally rinsed with 20 percent nitric acid for collection of water for cation analysis.

At each sampling site, in situ measurements (pH, water temperature, and specific conductance) were made using a Myron Ultrameter. Alkalinity concentrations were measured in the lab within forty-eight hours of collection by manual titration. Other samples were refrigerated until they were analyzed in the spring of 2014. Cations were analyzed using a quadruple ICP-MS in the Department of Geological Sciences. Anions were analyzed using an ion chromatograph at the Bureau of Economic Geology. Repeat analysis of samples with anomalously high concentrations of Cl, Na, and NO3 were conducted. A principal components analysis (PCA) was used to help determine source waters and influences on creek water compositions. Creek water discharge measurements during the sampling period were taken from the City of Austin database at the 24th Street monitoring site.

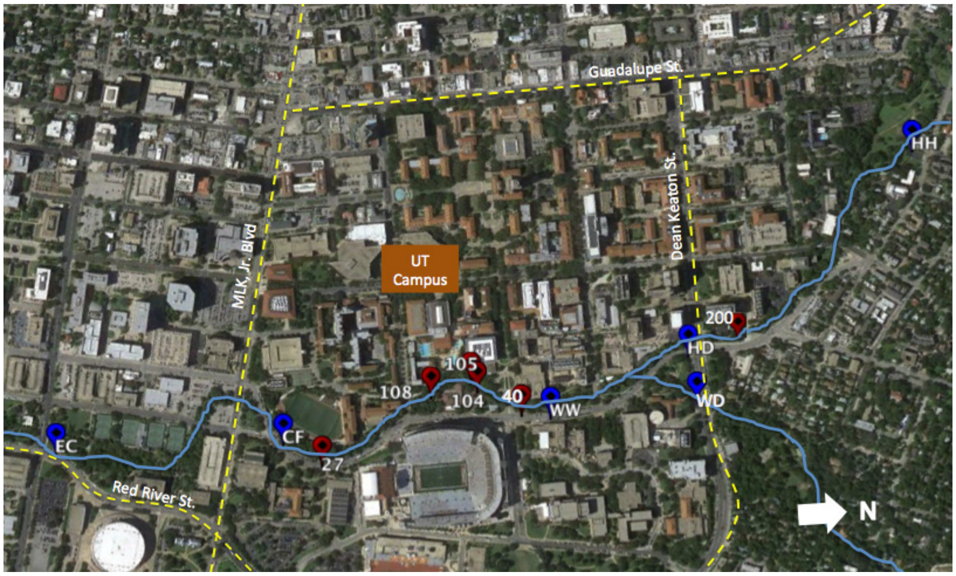

Figure 1: Map of sampling sites around Waller Creek.

Figure 1 (pictured above) is a map of sampling sites along Waller Creek, which flows from north to south. The creek is delineated with light blue lines, major road ways are marked by yellow dashed lines, sites in the creek are indicated as blue circles, and anthropogenic tributaries (ie. pipes) are indicated by red circles. The majority of the UT Austin campus spans, north to south, from Dean Keaton St. to MLK Blvd, and, west to east, from Guadalupe Street to Red River Street.

3. Results and Discussion:

3.1 Geochemical Evolution of Creek Water

Concentrations of analytes were plotted against distance to determine: i) if there was a significant difference between upstream to downstream sites during baseline conditions, and ii) variations within creek water through out the UT Austin campus. There were no substantial changes in compositions when comparing the water compositions from the north end of campus (HH) to the south end of campus (EC), however there is observable variability between sites within the boundaries of the UT Austin campus. There are noticeably different concentrations of NO3, Cl, and F at CF when compared to WW, suggesting the retention or addition of solutes or dilution of solute concentrations along this reach of the creek. Note that five anthropogenic tributaries were monitored along this reach.

3.2 Compositions of anthropogenic tributaries (ie. pipes)

Pipe compositions were unique when

compared to each other and the creek water by key constituents and chemical properties. The range of pipe water compositions is best represented by sites: 40, 108, 105, and 200 (Figure 1).

Pipe 40 is located beneath the San Jacinto and 23rd Street footbridge, and discharges from the East bank of campus. The most distinguishing characteristic of pipe 40 is the anomalously high NO3 concentrations, ranging from 55 ppm to 120 ppm. The Texas Commission on Environmental Quality (TCEQ) standard for NO3 in freshwater streams is 10 ppm, and natural undisturbed freshwater systems typically have much lower concentrations. Anthropogenic sources of NO3 can be fertilizers, untreated or partially treated wastewater, animal waste, or atmospheric deposition. Other key analytes found in this pipe are concentrations of Na (40 to 50 ppm), and Cl (70 ppm to 80 ppm). High Cl concentrations are a typical indicator for treated water, and paired with the Na and NO3 concentrations are indicative of wastewater. Trace elements characteristic of wastewater such as B, Ba, and Br were also detected at elevated levels.

Pipe 108 discharges from atop a steep bank from the Western side of campus, and located directly behind the Gregory Gym Aquatic Complex. During monthly monitoring, this pipe consistently had the highest specific conductance of every monitored site. Two key constituents, Na and Cl, are identified from this site due to their high concentrations (>250ppm and >400 ppm, respectively). Upon comparison of a Gregory Gym swimming pool water sample and a pipe sample taken on the same day, the pool water had much higher concentrations of Na and Cl (1000 to 2000 ppm). Due to the location of the pipe as well as its composition, it is suspected that the pipe discharge could be diluted swimming pool water discharge.

Pipe 105 is located behind the CLA building, and was actively discharging during each sampling event. Since the completion of this study, however, it has been noted that discharge from this pipe has ceased. The water that discharged from this pipe had a pH of 9.5, relatively high compared to natural freshwater streams (pH of 6.5 to 7.5). Water compositions from this pipe were nearly identical to tap water compositions and respective concentrations (Figure 3). Although this pipe has since been shut off, it is still an example of municipal water recharging the creek and supports previous findings that a significant portion of creek base-flow is municipal water.

Pipe 200 is a storm water drainage pipe, located on the Northwest tributary near the San Jacinto and Dean Keaton bridge. It is dry during base flow conditions, and was monitored only during the storm event sampling. Samples from this pipe best represent storm water runoff before mixing with creek water. Pipe discharge had concentrations of most solutes that were lower than concentrations measured the creek under base flow conditions, except for select heavy metals (Al, Pb, Zn, Cr, Fe) that occurred in higher concentrations in the pipe discharge than in the creek. During the storm event, concentrations of these same heavy metals increased in the creek, whereas all other constituents were diluted. This indicates that the creek is sensitive to storm water runoff. These metals can source from roadways and automobiles.

Pipe 27 discharges from the Eastern bank and is near the Darrell K Royal Texas Memorial Stadium. It seems it could be influenced by several sources, as it carries urban tracers such as Cl, F, and relatively high concentrations of NO3 (up to 55 ppm). During the storm event, the amount of flow from the pipe increased substantially, and constituent concentrations were diluted. Thus pipe 27 could be influenced by wastewater, or irrigation and storm runoff.

3.3 End-members of creek water composition

Several key characteristics and anthropogenic constituents found in pipes were also detected in creek water compositions. A principal components analysis (PCA) illustrates four end-members of creek and pipe water compositions: storm water, tap water, wastewater, and pool water (Figure 2). A PCA is a statistical analysis that transforms the variability among many variables, such as individual cation and anion concentrations, into a smaller number of principal components (e.g., Factor 1 and Factor 2). The grouping and weighting of each the original variables on the newly delineated factors aids interpretation of key sources and/or processes responsible for the majority of variability in the original data set. From this analysis, we interpret positive Factor 1 to reflect wastewater input, negative Factor 1 to reflect storm water runoff, and positive Factor 2 to reflect swimming pool discharge.

This plot enables delineation of the different end-members – tap water, swimming pool water, suspected wastewater represented by Pipe 40, and measured storm water represented by Pipe 200. Furthermore, this plot illustrates the range of mixing between the end-members that occurs at different sites along the creek and in the anthropogenic tributaries. All of the creek water and pipe discharge compositions fall between the end-members, indicating that water compositions can be accounted for by various combinations of end-member mixing.

4. Conclusions and Implications

Evaluation of creek water and pipe discharge compositions along Waller Creek on the UT Austin campus suggests that there are four end-members which influence creek water: storm water runoff, municipal water, swimming pool water, and wastewater. Furthermore, this study demonstrates the direct discharge to the creek from pipes draining the UT Austin campus is of sub-par quality, with either unacceptably high NO3 or TDS concentrations. However, similarity of creek water compositions entering and existing within campus boundaries suggests that the net affect of the UT Austin campus on Waller Creek water compositions is not substantial. In other words, creek water enters campus as poor quality and UT Austin does nothing to improve it. It is concerning that the UT Austin campus has an adverse impact on the water quality of Waller Creek for several reasons. Wastewater is not only a public health risk, but can also lead to excessive nutrient loading in the ecosystem. High salt concentrations in swimming pool water and elevated metal concentrations in storm runoff can also have detrimental effects on aquatic, microbial, and riparian ecosystems located on and downstream of UT Austin campus. These results are consistent with a previous study that demonstrated that Waller Creek water compositions were influenced by municipal water and possibly wastewater.[5] In addition, this study presents a new finding that swimming pool water is a significant influence. If the University is to remain committed to sustainability, then it will need to address its impact on Waller Creek.

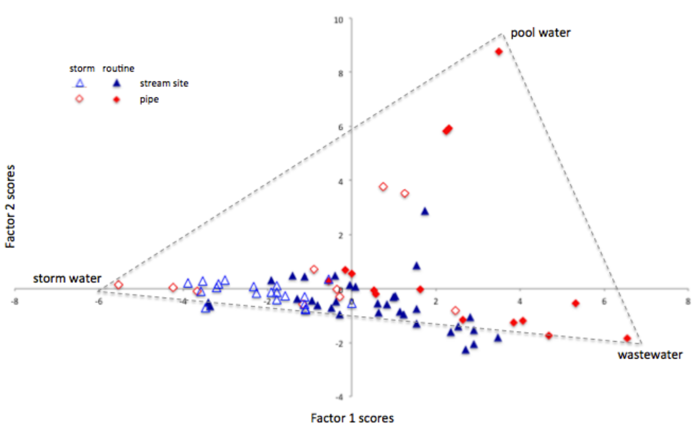

Figure 2: The principal components analysis (PCA) statistically illustrates end-members that influence creek water composition.

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