Zaragoza Rain Tank Passive Drawdown Flow Rate Determination

SR-16-07, April 2016

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Abstract

In an effort to decrease peak discharge rates, modify stream hydrographs during stormwater runoff events and more effectively infiltrate stormwater, the City of Austin tested a self-emptying rainwater harvesting cistern using a buried passive pressure dripline (GEOFLOW WASTEFLOW CLASSIC) with overflow to a rain garden. A test to evaluate the flow rate of the drip line emitters at pressures ranging from 0-3 lb/in^2 (psi) was assembled. Results show an average flow rate of 0.25 gallons per hour per emitter, constituting an adequate passive draw down time from a rain cistern relative to City of Austin regulations. This flow rate can now be used to design systems capable of passively draining stormwater and functioning as self-emptying temporary stormwater detention.

Introduction

The City of Austin, Texas, recognizes the ecological, social, and economic value of maintaining healthy stream systems and understands that being good stewards goes beyond monitoring and advocacy. Austin's streams were shaped by the immediate geological formations and meteorological systems found uniquely in this region. These systems have been tempered by extreme drought and intermittent flooding to create a resilient system capable of rebounding from those stressors. Urban development prior to and since 1839 when Austin became a city is a relatively new stressor that has negatively impacted the streams causing more intense stormwater runoff, extreme geomorphologic change, reduced ecologic function, and decreased baseflow. The effort to rehabilitate Austin's degraded urban stream network is a complex task without simple solutions and requires the coordination and cooperation of the entire community to be successful.

According to the stream functions pyramid, the first step to improving stream function is to improve the hydrology within the watershed (Harmon et al. 2012). A pilot project was initiated in 2016 by the City of Austin Watershed Protection Department to improve hydrologic function in the headwaters of the Waller Creek Watershed through the implementation of distributed small Green Stormwater and Rainwater Infrastructure (GSRI) projects on public and private properties including rain gardens, berms, swales and rainwater harvesting. Rainwater harvesting to reduce erosion and flooding and change hydrologic function remains an underused practice. Many uses of captured rainwater require an electric pump to pressurize the system and transport the captured water. As a result, many of the system accessories are designed to work with electrically pressurized systems. In our effort to create cost effective, low maintenance, long lasting systems we are designing systems using only the pressure from the hydraulic (elevation) head of the rain water in the storage tank for dispersal.

Because above ground standing water has the potential to cause public health concerns, our goal is to use a passive subsurface distribution system to infiltrate the harvested water from the storage tank into the soil. The method we are testing uses a drip line and emitter system (GEOFLOW WASTEWATER CLASSIC) that was designed for the land application of treated wastewater. The manufacturer of the drip line has only tested the flow rate of the emitters between 10 and 45 psi (Table 1). The pressure at which our passive system will be working is less than 3 psi. Although we investigated several dripline manufacturers, the GEOFLOW product was the only one that was reported to work at such a low pressure range. However, the emitter flowrates in this low pressure range have not been previously determined. This project measures GEOFLOW dripline emitter flow rates under the low pressure of our passive rainwater distribution system to identify a product that is sufficiently easy to install and maintain for use in our upper Waller Creek restoration project and other GSRI in general.

Table 1. Flow rate versus pressure of GEOFLOW CLASSIC WASTEWATER dripline. gph=gallons per hour. http://www.geoflow.com/wastewater/w_pdfs/classic.pdf

Pressure	Head	Flow Rate
10 psi	23.10 ft.	0.81 gph
15 psi	34.65 ft.	1.00 gph
20 psi	46.20 ft.	1.16 gph
25 psi	57.75 ft.	1.31 gph
30 psi	69.30 ft.	1.44 gph
35 psi	80.85 ft.	1.57 gph
40 psi	92.40 ft.	1.68 gph
45 psi	103.95 ft.	1.80 gph

Methods

For this experiment a 1,150 gallon polyethylene tank was installed and outfitted with a first flush system (30 gallons), an overflow pipe, a vertical pipe to hold the depth sampling hose, and several valves to allow for simultaneous tank drawdown connections (Figure 1). The first flush system is a simple bypass in the downspout conduit that intercepts the flow through the conduit until the capacity of the system is full at which point the flow continues on to the rain tank. The first flush system empties through a 1/8” orifice in the bottom of the 30 gallon barrel which is diverted to a rain garden. The overflow from the rain tank flows out of the tank overflow pipe and is diverted into a series of rain gardens. The rain tank is set up to capture the runoff from an 1,112 ft^2 section of (Figure 2) roof on the eastern side of the Zaragoza Recreation Center at 2608 Gonzales Street in eastern Austin, Texas. Based on the location of the outlet manifold and tank overflow line, the effective capacity of the tank is approximately 987 gallons. This size tank is able to hold 77% of a two inch storm event.

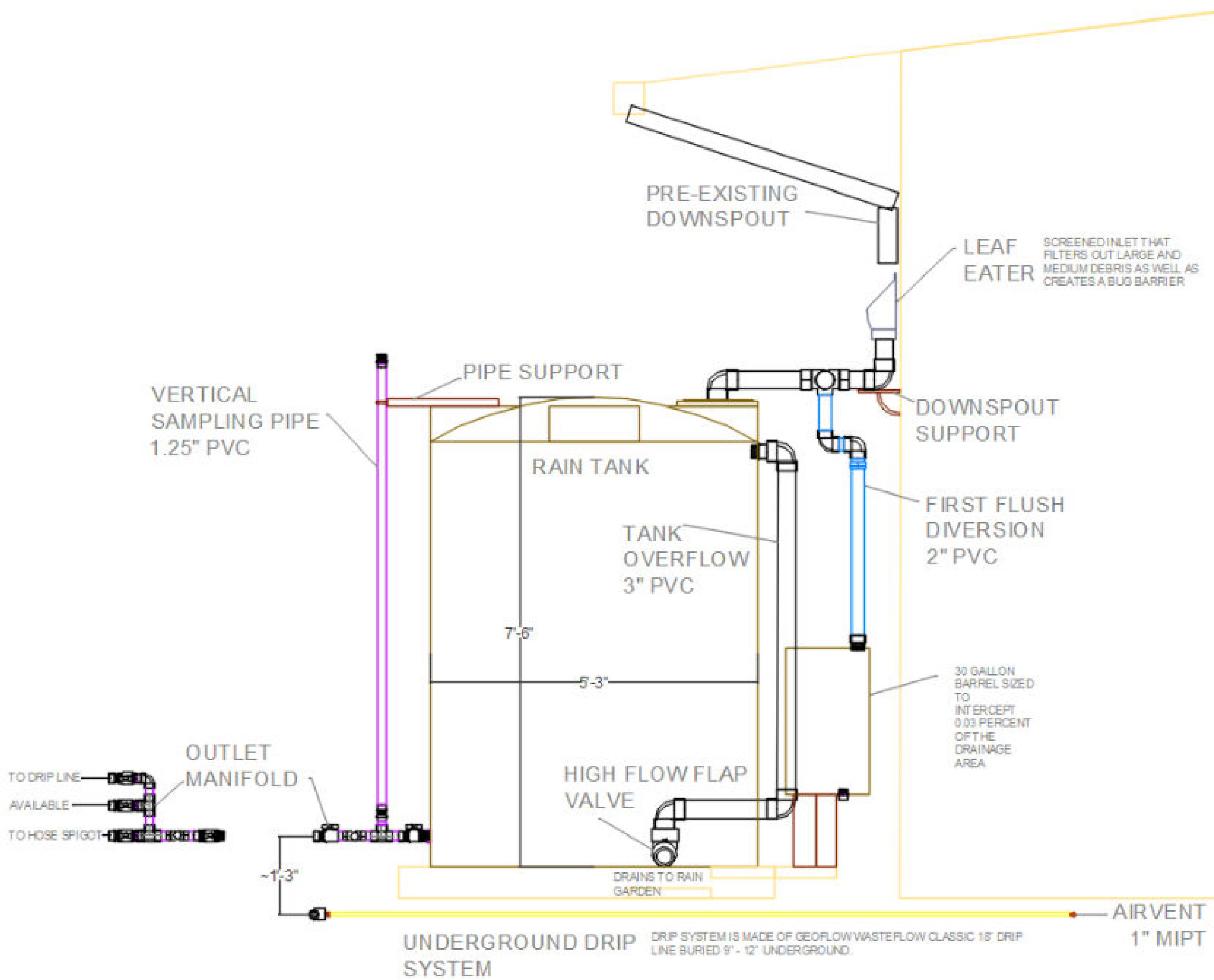

Figure 1. Zaragoza rain water harvesting and dripline system.

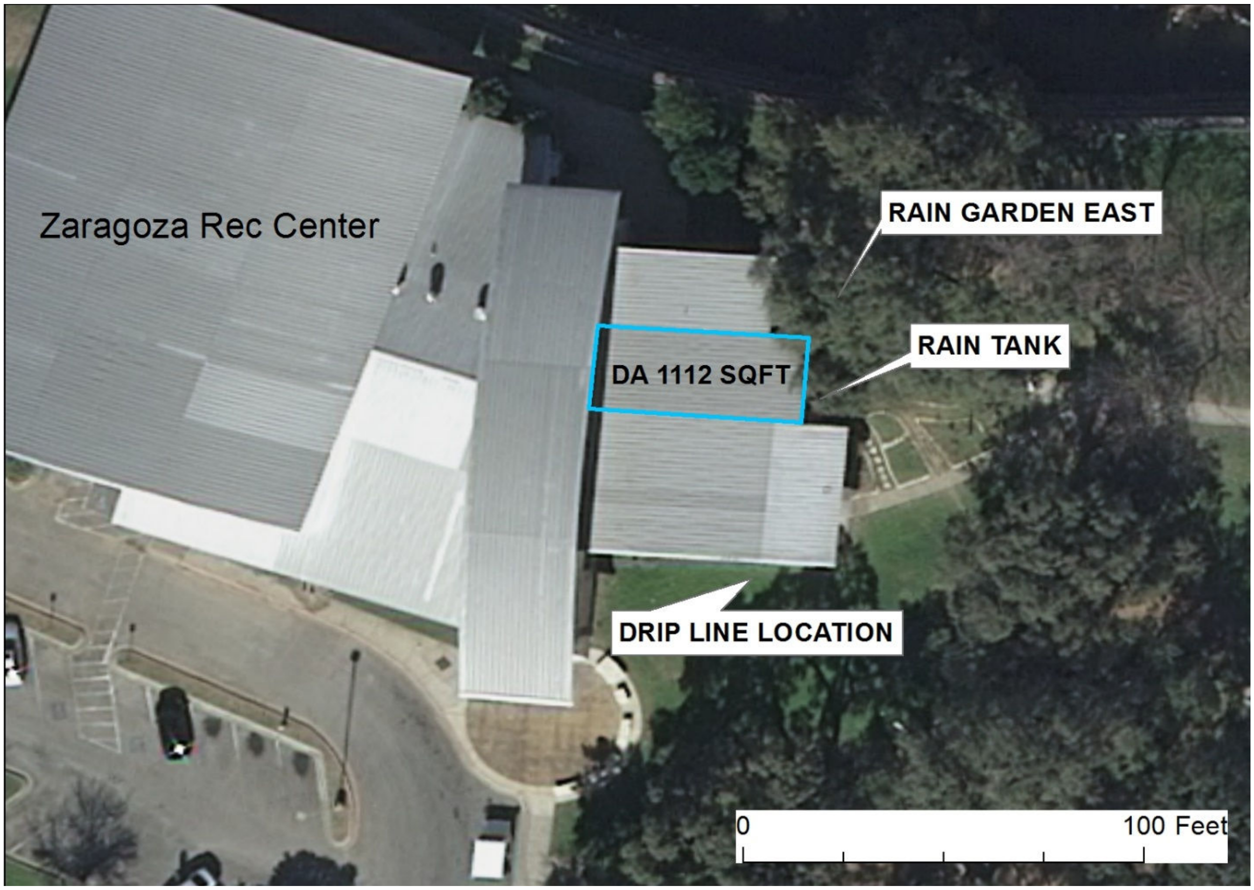

Figure 2. 1,112 ft^2 roof drainage area for the rainwater harvesting system at Zaragoza Recreation Center.

The water level in the tank was monitored using an ISCO Signature Flow Meter as the data logger and a TIENet 330 Bubbler Level Sensor. The data logger, bubbler, and 12 volt battery power supply were housed in an enclosure mounted to the concrete foundation of the rain tank. The depth sensor hose extended from within the enclosure, across the tank, and into the top of the vertical sensor pipe where it was fastened with silicone to the inside bottom to prevent it from floating when the vertical pipe filled with water. The hose was fastened such that it is close to the bottom of the tank outlet manifold and was referred to as zero feet of head level in the tank. Measuring from this point down to the depth of the dripline and adding it to the height of the water reading in the tank gave total height used for calculating head level of the system.

Draw down was measured in two parts, with the first part being conducted with the drip line above ground and the second part conducted with the drip line below ground. For the first test, a 50' coil (34 emitters) of the GEOFLOW drip line was placed above ground at a known level below the water surface elevation of the tank. With the dripline above ground the rate of draw down for the pipe was recorded and the average rate of flow per emitter was calculated for the dripline. The flow rate of the emitter must be greater than the minimum level of 0.24 gallons per hour (gph)—the flow rate necessary for 34 emitters to drain a 987 gallon tank in 120 hours—as required by the City of Austin Environmental Criteria Manual section 1.6.7.D. If the first test of the system failed to satisfy City of Austin criteria, then the second test would be postponed while another method of infiltration was considered.

For the second test, 60.5' of the dripline was buried 9" below the surface of the soil and the evaluation was repeated using a full rain tank. The second test had 41 emitters (7 more than the first test) and needed to have a minimum flow rate of 0.20 gph per emitter. This second test was to verify that the drip line will demonstrate similar behavior below as it did above ground.

For the first test the data logger was programmed to record date, time, and depth at one minute intervals. These data were uploaded to a Flow Link Server. In the Flow Link Server depth was converted from meters to feet. Data capture continued until the rate of change was zero. Data for the second test, with the drip line buried 9" underground and a total of 12" below the outlet manifold, was collected at one minute intervals. Other than the burial of the drip line, parameters were identical for both tests. These data were used to generate regression equations to calculate rate of discharge per hour per foot of head in the tank.

Results

The rate of flow in the first test was equal to or greater than the calculated minimum necessary rate for draw down (0.24 gph). Data collection for Test 1 began on March 2nd, 2016 at 16:39 and finished 6 minutes later at 16:45 when the pipe had been drained completely. Of the seven data points collected, only three points (Table 2) appeared to represent consistent draw down measurements. The rapid drawdown of tank water level indicated that the conditions were met to initiate the second test. The average flow rate of the three points was 0.25 gph.

Table 2. Data collected and calculated for Zaragoza Test 1.

Date	Value	*Value + 12"	Volume	Head Pressure	**Flow Rate	∞Useable Data
	IN	FT	GAL	PSI	gph	
3/2/2016 16:39	90.61	7.55	0.505906	3.25		
3/2/2016 16:40	83.91	7.99	0.468498	3.44	0.066	
3/2/2016 16:41	76.12	7.34	0.425003	3.16	0.077	Begin
3/2/2016 16:42	42.66	4.56	0.238185	1.96	0.330	yes
3/2/2016 16:43	14.98	2.25	0.083638	0.97	0.273	yes
3/2/2016 16:44	1.24	1.10	0.006923	0.47	0.135	yes
3/2/2016 16:45	0	1.00	0.000000	0.43	0.012	End

* Twelve inches were added to the level of the tank to account for the depth of the dripline.
** This is the average flow rate per emitter.
∞ Only data points with consistent drawdown rates were used.

Data evaluation for Test 2 began on March 20th, 2016 at 18:15 and ran until March 25th, 2016 at 7:25 when the tank level reading was 0.04 feet. It rained once during that period and the runoff from the rain contributed to a rise in the tank level. Data influenced by the rain event was discarded from the analysis. Data below one foot of head was also not considered for the analysis because the bubbler level only measured to the outlet manifold and was not able to measure below one foot. Table 3 shows the intervals of data used for the evaluations.

Table 3. Data collected and calculated for Zaragoza Test 2.

Beginning period	End period	Interval used
03/20/2016 08:15	03/23/2016 18:22	1 minute
03/24/2016 07:31	03/25/2016 07:25	1 minute
03/20/2016 18:15	03/23/2016 15:15	1 hour, 4 hour
03//23/2016 16:15	03/25/2016 07:25	1 hour, 4 hour

The data was evaluated at one minute (instantaneous), one hour (mean), and four hour (mean) intervals. A regression analysis was performed on each set of intervals (Figure 3-5). The average flow rate for the one hour data was 0.27 gph. A considerable change in flow rate was evident when the water level was 1.9 ft. The data was then split into two groups (1-1.9 ft and >1.9-7.4 ft) and a regression equation was fitted to each section for the mean one hour data. (Figure 6).

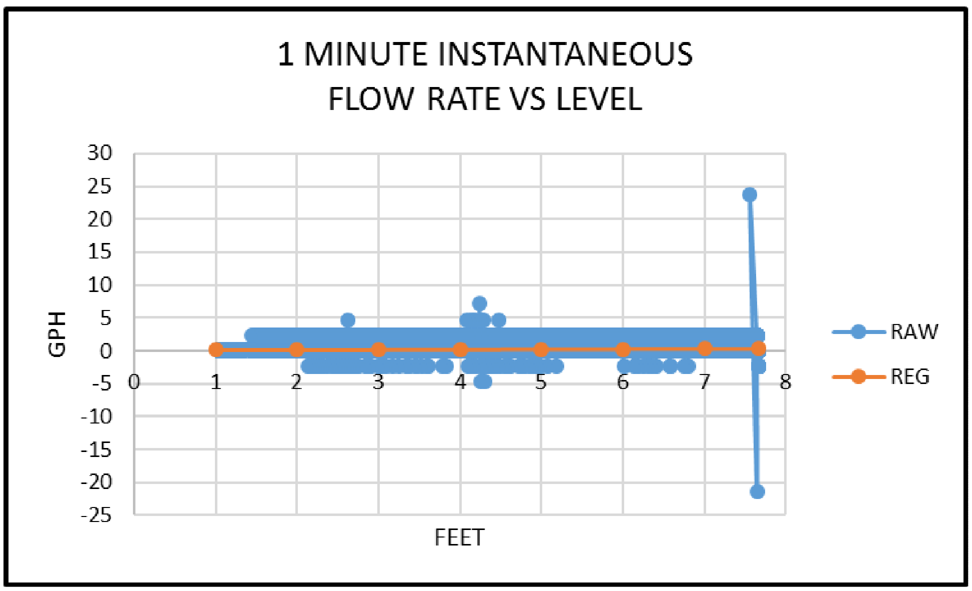

Figure 3. One minute instantaneous flow rate and level data plotted against regression line of data. Adjusted R^2 = 0.001812, P Value = 0.0004 Y=0.019*(X)+0.171.

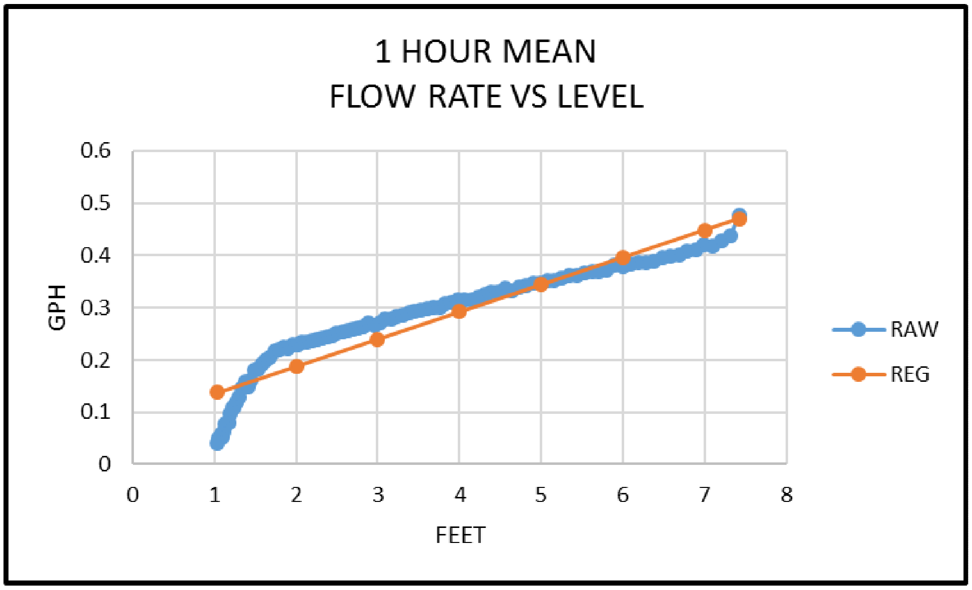

Figure 4. One hour mean flow rate and level data plotted against regression line of data. Adjusted R^2 = 0.879674, P Value = 3.18E-45, Y=0.052(X)+0.084.

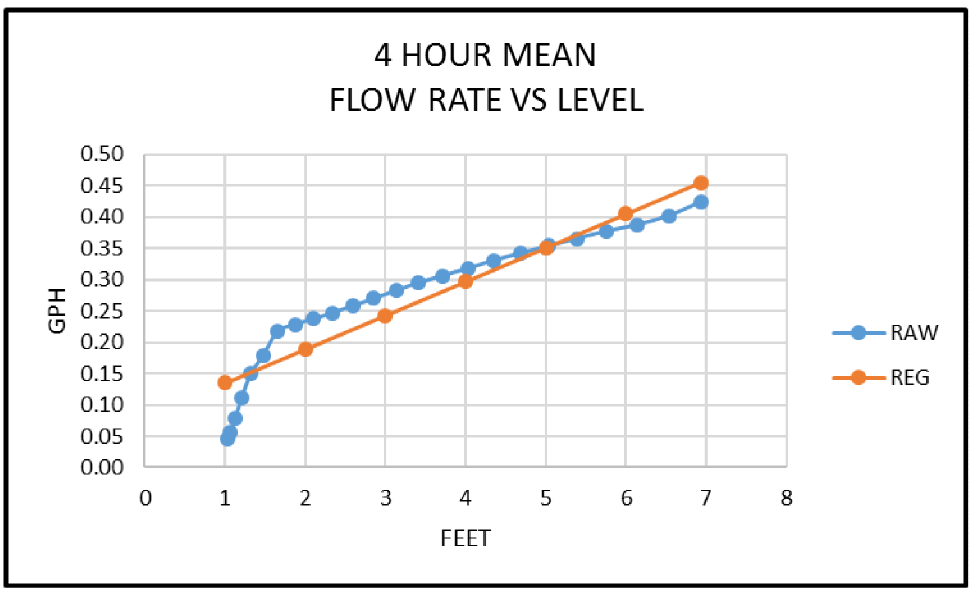

Figure 5. Four hour mean flow rate and level data plotted against regression line of data. Adjusted R^2 = 0.863446, P Value = 3.38E-11, y=0.054*(x)+0.081.

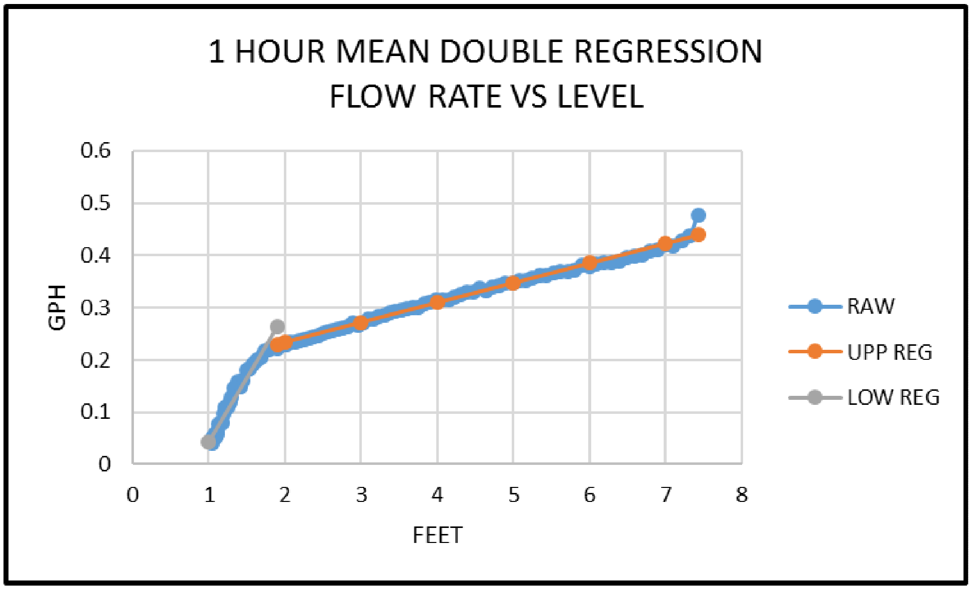

Figure 6. One hour mean flow rate and level data plotted against two regression lines of the data. UPP REG Adjusted R^2 = 0.988703, P Value = 3.53E-67, Y=0.038*(X)+0.158 and LOW REG Adjusted R^2 = 0.962048, P Value = 1.71E-19.

Discussion

Test 1 yielded an average flow rate of 0.25 gph per emitter above ground. Since the condition for Test 1 to proceed to Test 2 was a minimum flow rate of 0.24 gph, Test 2 was performed.

To maximize the infiltration area of the excavated trench, as well as to expedite the installation of the system, the dripline was connected directed to the tank manifold and buried. The entire 60.5' of trench received dripline. Test 1 used only 50' of hose and 34 emitters, while Test 2 had 60.5' of dripline and 41 emitters. Thus, the emitters in Test 2 could have a slower flow rate than was needed in Test 1 and still meet the 120 hour draw down time requirement.

A storm event occurred March 8th to 9th and provided enough runoff to fill the rain tank to capacity. On March 20th the valve was opened around 18:00 and Test 2 began.

The one minute data set was not used due to the amount of noise caused by sequential sensor detections of small incremental changes in level over a longer slow rate of decline. The incremental flowrate calculated from these data was positive and negative and the result was not a good representation of what was observed as the tank was emptied. When the points were averaged over an hour the sequential tank levels appeared as observed and the calculated flowrates were reasonable. The average emitter flow rate for the one minute data was 0.246 gph and the tank drained down in 106 hours, which equals 1,070 gallons and is reasonably close to the calculated 987 gallon functional capacity of the tank. The TIENet 330 Bubbler Module has an accuracy of 0.007 ft at 72°F (Appendix A) so there should have been little effect from error until the tank was almost empty.

The one hour mean interval regression had a lower P Value and higher adjusted R^2 than the four hour mean interval making the one hour data set the chosen data for the final analysis. Visual inspection of the slopes of the one hour data graph (Figure 4) suggested the data would be better represented by piecewise linear regression equations. Analyzing the data with upper and lower regressions from 7.4 to 1.9 and 1.8 to 1.0 feet of head enables us to create two equations that explain a larger amount of variability as evidenced by an adjusted R^2 of 0.878 for the single regression equation and adjusted R^2 of 0.989 for the upper (major) grouping and 0.962 for the lower (minor) grouping. The equations from the two regression analysis were used to create tables representing estimated flow rate relative to hydraulic head depth (Table 4) and pressure (Table 5) at uniform intervals.

Flow Rate vs. Head	
Emitter Rate	Head Depth
gph	FT
0.04	1
0.23	2
0.27	3
0.31	4
0.35	5
0.39	6
0.42	7

Table 4. Flow rate in relation to head depth of water in rain tank. For depths below 1.8 FT use the equation Y=0.245(X)-0.202 to calculate gph otherwise use Y=0.038(X)+0.158.

Flow Rate vs. Pressure	
Emitter Rate	Pressure
gph	PSI
0.08	0.5
0.25	1
0.29	1.5
0.33	2
0.38	2.5
0.42	3

Table 5. Flow rate in relation to pressure of water in rain tank. For pressures below 0.7 PSI use the equation Y=0.245(X/.43)-0.202 to calculate PSI otherwise use Y=0.038(X/.43)+0.158.

Conclusions

The GEOFLOW WASTEWATER CLASSIC dripline performed at an average flow rate of 0.25 gph at pressures less than 3 psi. The measured flow rate was greater than the minimum flow rate necessary to comply with City of Austin criteria. Thus, the GEOFLOW WASTEWATER CLASSIC may be considered an effective and simple method for distributing water at pressures lower than 3 PSI within required draw down times for self-emptying rainwater harvesting systems.

Providing that the infiltration of the soil is sufficient, the rate of drawdown can be increased by using a dripline with more emitters per foot, doubling up the line in the existing trench, or adding more dripline zones. If the rain tank is sized such that the regulatory water quality capture volume requirement for the system is less than the overall capacity of the tank, then the water quality volume (upper portion of the tank) can be drawn down at the higher pressure and will have a higher average flow rate. The regression equation can be used to determine the expected flow rates.

Recommendations

The product tested here should not be considered the only product of its type that will work in this manner. It is likely that there are other products similar or different that would be ideal as a solution to this same problem. This test was not intended to be a comprehensive study of driplines but instead an evaluation to validate the effectiveness of this one product. We will continue to evaluate other products and hope that anyone finding other effective and economic solutions will inform us.

Based on the manufacturer's data for loss of pressure due to length of pipe (Figure 7) it is recommended to keep the distribution lines equal to or less than 50' and to make sure that there is a filter and clean-out set up for each line. The life expectancy and long term maintenance of this product are unknown. Additional identical evaluations should be conducted in future years to evaluate consistency and long term viability.

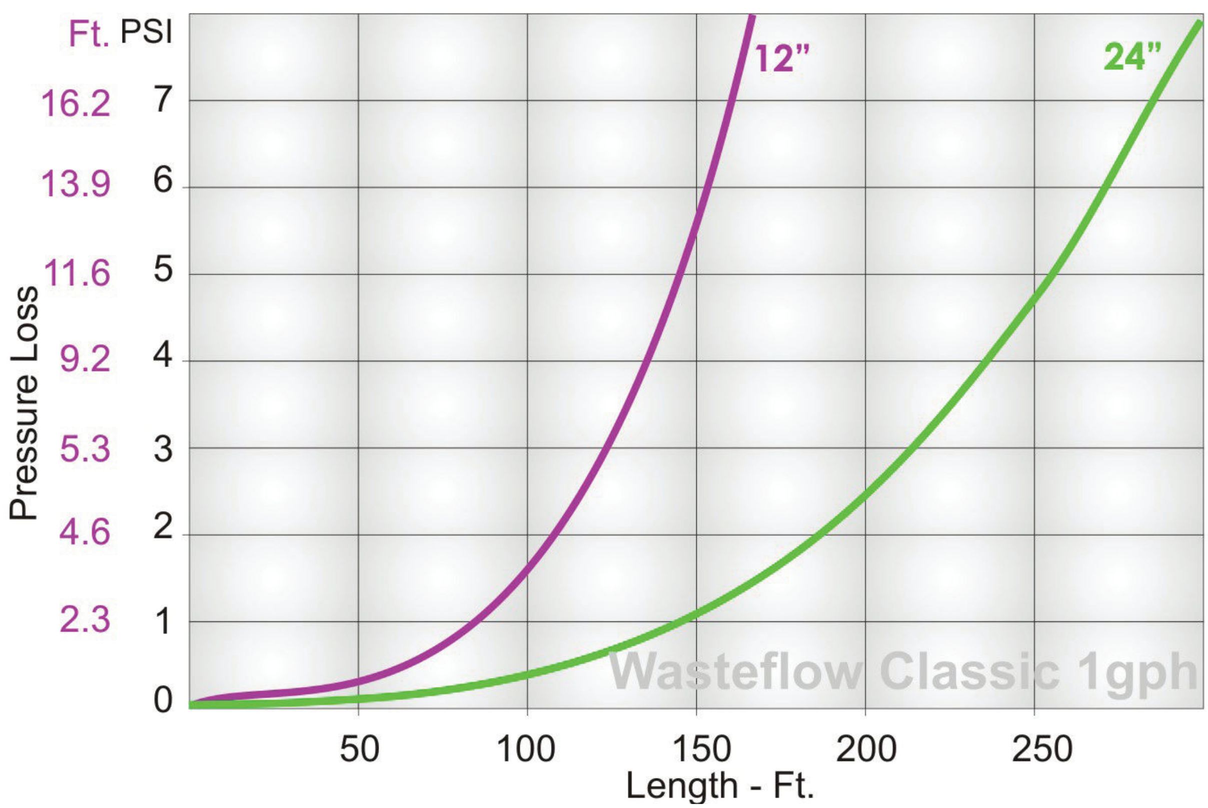

Figure 7. Pressure loss versus length of run for GEOFLOW WASTEFLOW CLASSIC dripline.

References

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. *A Function-Based Framework for Stream Assessment and Restoration Projects.* US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006

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GEOFLOW. 2016. WASTEFLOW Classic. http://www.geoflow.com/wastewater/w_pdfs/classic.pdf.

Appendix

A.

TIENet® 330 Bubbler Module	
Level Measurement Range:	0.003 to 3.05m (0.01 to 10 ft)
Level Measurement Accuracy:	+/-0.002m @ 22 °C (0.007 ft @ 72 °F)
Operating and Storage Temperature:	-18° to 60 °C (0 to 140 °F)
Temperature Compensation Range:	0° to 60 °C (32° to 140 °F)
Temperature Coefficient (w/in compensated range):	±0.0003 x Level (m) x Temperature Deviation from 22 °C. ±0.00017 x Level (ft) x Temperature Deviation from 72 °F.