Final Report

JOINT PROJECT BETWEEN
INTERSTATE ENVIRONMENTAL COMMISSION
AND
EDESIGN DYNAMICS, LLC

Implementation and Assessment of the Effectiveness of the Green Infrastructure Technology in Newark, NJ

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1. GENERAL OVERVIEW

This report summarizes work performed by eDesign Dynamics (EDD) in collaboration with the Interstate Environmental Commission (IEC) through a grant administered by New England Interstate Water Pollution Control Commission and funded by the US EPA. The project title is "Implementation and Assessment of the Effectiveness of the Green Infrastructure Technology in Newark, NJ." Its purpose is to assess the effectiveness of green infrastructure (GI) technologies, (also known as low impact development (LID) technologies) at reducing urban runoff. Because the city has a combined sewer system, Newark, NJ, is an appropriate location for this project. Incremental reductions in the volume of runoff contributed to the combined sewer systems from individual lots can, during wet weather, reduce the frequency and volume of combined sewer overflows (CSOs). eDesign Dynamics and Interstate Environmental Commission are collaborating with the NY/NJ Baykeeper, the New York-New Jersey Harbor Estuary Program, the City of Newark, and the Greater Newark Conservancy (GNC), on reaching this goal. All above-mentioned parties contributed in the selection of the project in Newark as a site for GI technologies to be implemented.

1.1 PROJECT OBJECTIVES

The project goals involved the construction and monitoring of a "green" stormwater management system that reduces urban runoff through engineered infiltration, detention, reuse and evapotranspiration functions. Because stormwater from the project site historically drains directly to the City's combined sewer system, there is a direct connection between runoff reductions achieved on this site through this design and the likelihood that replication of this design across Newark's urban watershed can reduce the frequency of CSOs to the Passaic River. The design captures precipitation falling directly on the project site, but also harvests runoff generated on adjacent roof areas. EDD collaborated with GNC to develop a landscape plan and stormwater management system that can store these inflows and simultaneously provide irrigation water for garden areas within the formerly vacant lot.

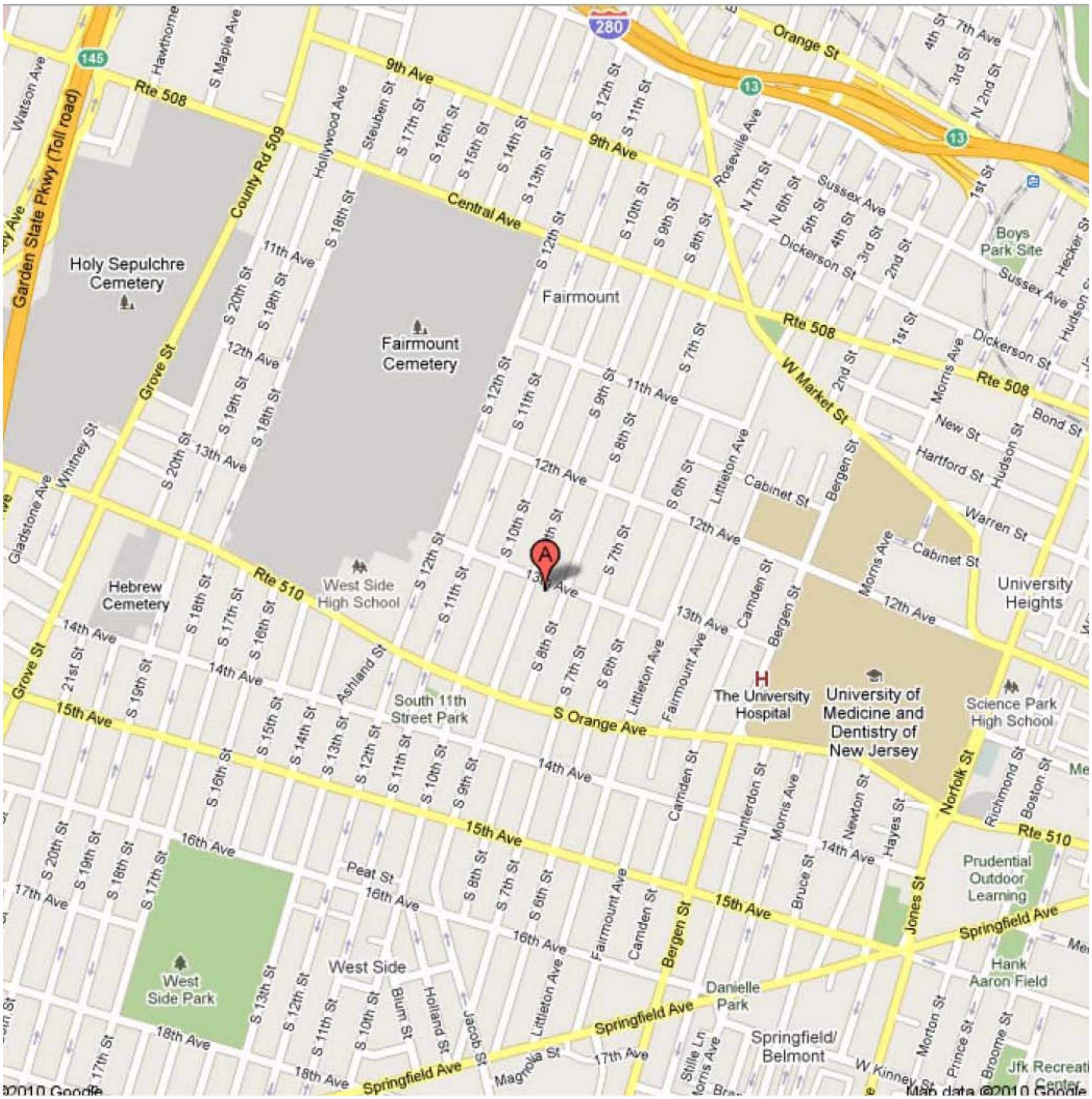
The stormwater management system is configured to capture and redirect rainwater from adjacent properties for storage and reuse. When the storage capacity of the GI system is reached, overflows are directed first to an infiltration leach field, and finally back to the existing sewer system as a failsafe mechanism. The system utilizes a number of GI practices resulting in stormwater detention, retention, infiltration and irrigation reuse. EDD also designed and installed a water volume monitoring system with rain gauge in order to estimate the volume of water diverted away from the combined sewer system and subsequent reductions to CSOs for each rain event during the monitoring period.

1.2 SITE DESCRIPTION

The project site is located at 368 13th Avenue on a city-owned vacant lot along 13th Avenue between 8th and 9th Streets and across from the Thirteenth Avenue School in the West Ward neighborhood of Newark, New Jersey (see Figure 1: Site Within Regional Context). Its dimensions are 6.7 by 30.5 meters (or 204 m^2) and, until this project, its entire surface was compacted urban fill and demolition debris.

EDD worked directly with neighbors to establish access to adjacent rooftop areas for connection to the project site (i.e. to enlarge the GI pilot project's catchment area). The downspouts from two adjacent roofs are directed to the system: the downspout from 241 S 8th Street (approximately 105 m^2) and the garage at 272 S 9th Street (approximately 28 m^2). The GI system constructed on the principal lot receives and stores a portion of the harvested runoff for irrigation use. Volume in excess of storage capacity is provided an opportunity to infiltrate. A designed failsafe mechanism directs water that cannot infiltrate to the existing City sewer system.

Figure 1: Site within Regional Context



1.3 SYSTEM CONFIGURATION

Catchment

The downspout from 241 S 8th Street was disconnected from its direct connection to the combined sewer system and instead extended to a sediment trap and subsurface cistern installed at the project site (see Figure 2: Site Plan). The downspout from the 272 S 9th Street garage roof discharges directly to a “solo rain barrel” which can overflow to the subsurface cistern.

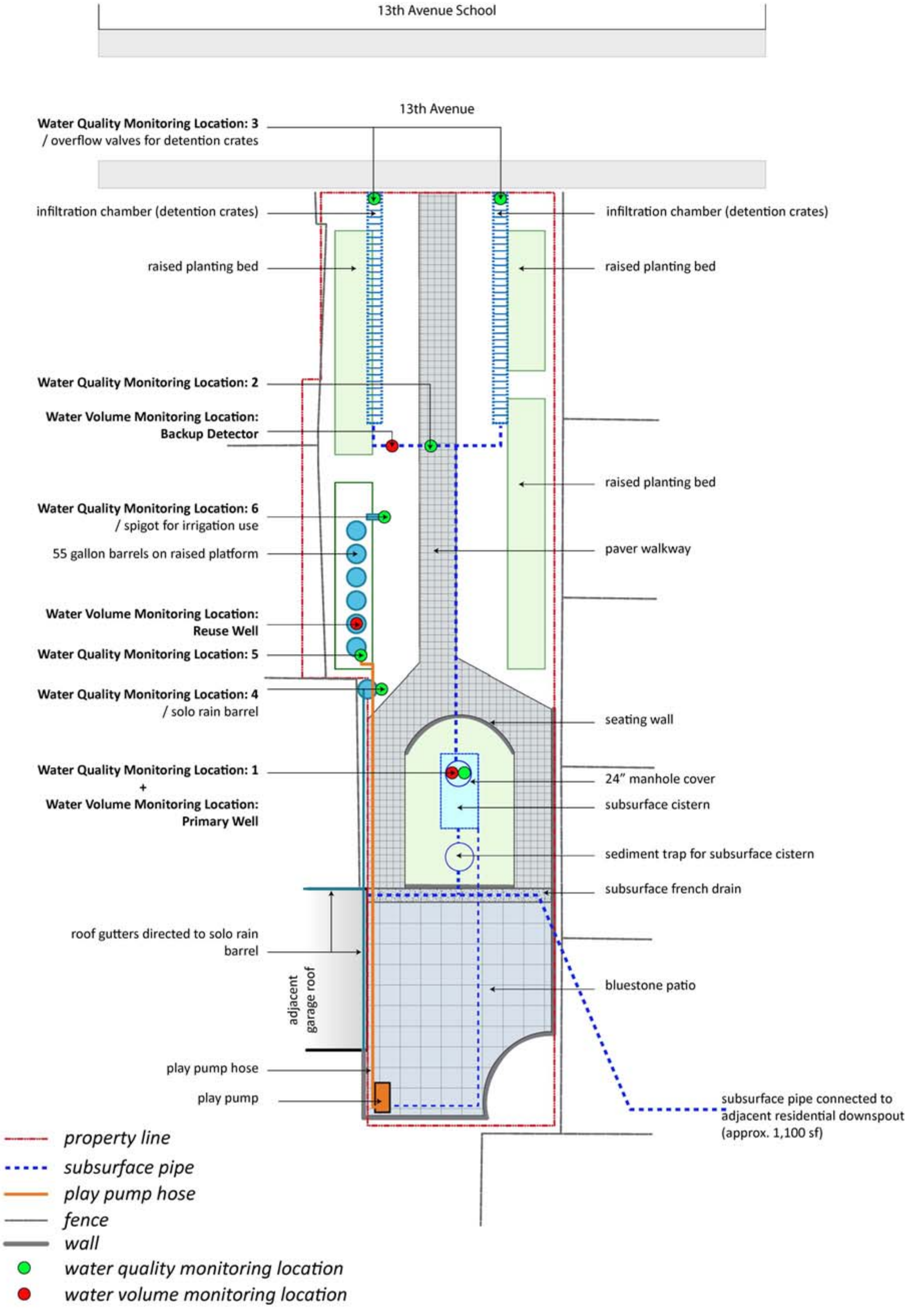
Storage and Infiltration

The cistern is constructed using a single StormChamber™, an open-bottom, high-density polyethylene chamber, wrapped in a 40 mil pond liner. The pond liner was added so that harvested rainwater could be stored for use in irrigation. Due to post construction soil settling, the total storage capacity of the cistern was reduced from 2,100 liters to approximately 1,500 liters. When the cistern capacity is exceeded, additional inflows are directed to two infiltration galleries each constructed with thirteen Atlantis Single Flo-Tank detention crates. When capacities of the crates are exceeded, excess precipitation flows overland across the sidewalk, and into the street where it then follows the curb and enters existing catchbasins at the street end. Note that due to the compacted soils present on the project site prior to this project; most runoff generated on the project site followed this flow path to the existing combined sewer system.

Irrigation Reuse

The cistern is configured to operate as a detention/retention tank that holds a volume of water for slow release to the infiltration galleries (detention) while the remaining volume is stored for reuse by irrigation (retention). The detention volume inside the cistern is approximately 520 liters, and the retention volume approximately 985 liters. Irrigation water is drawn up from the cistern by means of a human powered “treadle pump” and stored in six above-ground 55-gallon (208-liter) barrels. The barrels are covered to limit mosquito breeding. When irrigation water is needed, the gardener or a community member fills the barrels by operating the pump. The planted areas are then irrigated by means of a hose connected to the outlet spigot of the barrels. In addition to the adjacent roof sources, the cistern also receives flow from the underdrain of a 25 m^2 bluestone pervious pavement patio installed at the top (south) end of the site. The total catchment area contributing directly to the cistern collection system is approximately 135 m^2. The patio area is not included as a direct connection as the timing and volume of the contributions from the drain are uncertain.

Figure 2. Site Plan



1.4 PROJECT SCHEDULE

Unforeseen impediments delayed the completion of the garden, which, in turn, necessitated an extension of the project's timeline. Consequently, the winter season was the earliest that the water quality sampling portion of the project could commence. The Greater Newark Conservancy (GNC), the entity responsible for coordinating post-construction site maintenance and upkeep, did not intend to operate the treadle water pump or make full use of the above-ground barrels between October, 2009 and May, 2010. Recognizing that certain components of the system would be idle during the winter months, because GNC did not intend to irrigate during this time, and in an effort to prevent unnecessary cold weather stress, EDD planned to delay installation of the pump until the spring, 2010. Additionally, GNC required spring and summer to complete construction of all components of the garden.

Accordingly, the project team discussed whether it would be best to proceed with the sampling plan [although the site would not be fully operational] in order to maintain the project's schedule or postpone sampling until the entire system was functional. Although the latter option would inevitably delay the project's completion date, the project team (IEC, EDD, NEIWPCC and EPA), agreed to defer sampling until May, at the start of the growing season when the site would be fully operational and equipped to meet the garden's irrigation needs. With the understanding that it was more beneficial to conduct monitoring under "truer conditions", when the entire GI network would be fully operable as intended by design of the site, a grant extension was approved to allow for an adequate amount of time to permit completion of the study. Sampling was then further delayed from May, 2010 to August, 2010. Due to GNC's work scheduling conflicts, construction did not resume until the summer of 2010. All green infrastructure technologies were installed by mid-July with monitoring systems up and running in late August, 2010. As it was intended that construction be part of a community process, working in collaboration with not-for-profit groups, the design team had to adjust the schedule to meet everyone's limitations.

Consequently, the revised plan did not permit proper investigation of seasonal variations. On the outset, EPA's review of the study and design included a comment regarding the lack of seasonal variability assessments achievable by the proposed methods pertaining to water quality fieldwork. However, this critique was reconciled because the original scope of work did not incorporate seasonality in the study objectives and thereby, did not require this component. Recognizing the potential importance of accounting for seasonal variation, the investigators will consider this element in future work.

1.5 PROJECT INSTALLATION

The landscaping and GI system installation was performed with labor provided by the Newark Prisoner Reentry Initiative with supervision and oversight from EDD in collaboration with GNC. This approach to construction integrated "green workforce training" and other social objectives of GNC into the project's implementation and was an exciting component of the overall pilot project. Several dozen laborers participated in the construction working side-by-side with EDD and the professional landscapers. Working with hand tools and power tools, the labor force watched the project site transform from an overgrown vacant lot to a finished public garden with a functioning irrigation system.

Soils within the lot prior to construction were composed of demolition fill and urban debris with high clay content. These conditions do not promote infiltration or plant growth. For this reason, soils across the site were enhanced with imported materials. Wherever excavation took place for locating pipes or buried fixtures, gravel was laid to provide pore space and enhance infiltration. All planted areas were provided high quality topsoil.

After construction was complete, the monitoring equipment and data logger were installed to measure water elevations at key points in the system. The water volume monitoring system became fully operational on September 3rd, 2010, three weeks before the end of the 2010 growing season (i.e. before the end of this season's irrigation).

2. WATER QUALITY MONITORING

IEC was responsible for the water quality portion of the project, including the collection and in-house laboratory analysis of field samples. In the spring of 2010, IEC visited the site with EDD and GNC to finalize the logistics of the sampling plan and the monitoring locations. As per the schematic (refer to Figure 2: Site Plan), minor site design changes, which were necessary after the initial draft of the QAPP, required a few modifications to the sampling stations, with respect to their exact location. The current site design includes a series of six interconnected rain barrels, which can be filled with collected water by the use of a treadle pump, which is connected to the subsurface cistern. After each rainfall, GNC will be responsible for pumping water through this system. The water will be stored in the rain barrels and used on-site to water the planting beds and maintain the garden.

Although a final QAPP was approved; additional punch list work was required on-site before the site was completed. Following the official completion of the project site in mid-July 2010, IEC was granted access by GNC and EDD and proceeded with the field monitoring phase. Due to the above-mentioned site design modifications, it was decided that IEC would collect a total of six samples per event, instead of the four samples that were originally outlined in the QAPP. The chart below represents the final sampling locations and descriptions.

Table 1. Monitoring Locations

Monitoring Locations	Description
1	Subsurface cistern
2	Test well in the center of the permeable pavement
3	Blow off valve for subsurface detention crates
4	Grey solo rain barrel
5	Treadle pump discharge into barrel line for reuse
6	Reuse spigot at end of barrel line

As outlined by the QAPP, IEC completed 3 wet-weather events to evaluate the water quality of samples recovered from various locations within the GI system. The QAPP required a minimum of 0.15 inches of rain for a storm event to be considered wet weather and the sampling to be performed within 24 hours of the storm event. In all three events IEC met these requirements. Each sampling run required the collection of the following field measurements: temperature, specific conductance, pH and dissolved oxygen; subsequently, (in-house) laboratory analyses were conducted to determine additional physicochemical parameters and pathogen indicators including settleable solids, turbidity, chlorides, metals, fecal coliform and Enterococcus.

2.1 QUALITY ASSURANCE/ QUALITY CONTROL

IEC field and laboratory staff followed all sampling methods described in the approved QAPP and IEC's own sampling manuals. These procedures include but are not limited to care for sampling equipment, sample handling, preservation, storage, custody, transport and packaging.

IEC field and laboratory staff followed all laboratory methods described in the approved QAPP and IEC's own laboratory manuals. These procedures include but are not limited to analytical procedures, calibration requirements, precision, accuracy, method detection limits and completeness.

The Interstate Environmental Commission's laboratory is a nationally certified environmental facility. The Commission's laboratory is accredited by the National Environmental Laboratory Accreditation Program, known as NELAP, which focuses on the technical competence of the entity monitoring the environment. The New York State Department of Health (NYS DOH) is the primary accrediting authority for the majority of the laboratory's certified parameters. Through NYS DOH, the Commission's laboratory holds NELAP certifications for a list of parameters in this project except Dissolved Oxygen (DO). Currently NYS DOH does not provide accreditation for DO, so the Commission's laboratory also holds primary NELAP certification through the New Jersey Department of Environmental Protection (NJ DEP) for DO. Furthermore, the Commission's laboratory also holds secondary NELAP certification through the NJ DEP and the CT Department of Health for those parameters that it already holds primary certification from the NYS DOH.

2.2 WATER QUALITY RESULTS

Run 1.

IEC performed its first round of sampling of the site on August 23, 2010. Field monitoring commenced on-site at 12:35 pm and ending at 1:40 pm. For the previous 24 hour period the estimated rainfall from the Nation Weather Service (NWS) – Newark Daily Climate Data was 0.29". It was sunny during the sampling. This round of sampling was successfully completed. Samples were collected from all six sampling points and analyzed for all parameters (Table 2A, Appdx. Table 1A).

Run 2

IEC performed its second round of sampling on September 13, 2010 starting at 12:35 pm and ending at 1:40 pm. For the previous 24 hour period the estimated rainfall from NWS – Newark Daily Climate Data was 0.56". It was sunny during the sampling. Due to sediment buildup in the system, IEC was only able to collect and analyze samples from 4 of the monitoring locations (Table 2B, Appdx. Table 1B). Sample locations #2 and #3 were dry at the time of the sampling.

Run 3

IEC performed its third round of sampling on September 17, 2010 starting at 11:50 am and ending at 12:15 pm. For the previous 24 hour period the estimated rainfall from NWS – Newark Daily Climate Data was 0.40”. It was partly cloudy during the sampling. Sediment buildup in the system was problematic again, limiting IEC to collect and analyze samples from 4 of the 6 monitoring locations for the full suite of water quality parameters; IEC was able to collect enough water from location #2 to permit analysis of all parameters except settleable solids and chlorides (Table 2C, Appdx. Table 1C). Sample location #3 was dry at the time of the sampling.

Table 2A. Interstate Environmental Commission Water Quality Results: Run 1

Sampling Location	Time (DST)	Temp. (◦C)	Conductivity (uS/CM)	D.O. (mg/L)	pH (S.U.)	Fecal Coliform (MPN/100ml)	Enterococcus (MPN/100ml)	Chlorides (ppm)	Settleable Solids (mg/L)	Turbidity (NTU)
1	13:15	21.6	41.2	6.28	7.65	150	2400	9	<0.1	4
2	13:27	20.8	13.8	6.89	7.33	<3	4	889	0.2	24
3	13:35	22.7	89.3	6.86	6.29	≥24,000	≥24,000	38	0.2	31.5
4	13:40	20.5	23.2	6.75	5.23	430	2400	4	>0.1	2
5	13:45	20.0	43.5	7.41	5.93	<3	230	6	0.2	36
6	13:50	20.6	2.9	9.78	7.04	2400	9	6	0.1	5

Table 2B. Interstate Environmental Commission Water Quality Results: Run 2

Sampling Location	Time (DST)	Temp. (◦C)	Conductivity (uS/CM)	D.O. (mg/L)	pH (S.U.)	Fecal Coliform (MPN/100ml)	Enterococcus (MPN/100ml)	Chlorides (ppm)	Settleable Solids (mg/L)	Turbidity (NTU)
1	12:35	20.5	76.2	4.82	7.84	<3	9	6	<0.1	3
4	1:05	49.4	17.7	5.46	7.58	9	430	10.5	0.1	3
5	13:30	66.7	24.1	5.79	7.11	<3	4	4	2	209
6	13:40	46.4	24.2	5.50	3.85	<3	9	4	<0.1	8

[1]Because of sediment build-up in the system there was no flow in sample location #2 and no flow in sample location #3, which prevented IEC from analyzing for any parameters at sampling locations #2 and #3

Table 2C. Interstate Environmental Commission Water Quality Results: Run 3

Sampling Location	Time (DST)	Temp. (◦C)	Conductivity (uS/CM)	D.O. (mg/L)	pH (S.U.)	Fecal Coliform (MPN/100ml)	Enterococcus (MPN/100ml)	Chlorides (ppm)	Settleable Solids (mg/L)	Turbidity (NTU)
1	11:50	19.6	31	5.52	7.03	430	75	4	<0.1	4
2	11:59	20.2	38.0	8.54	7.27	1500	930	NA[1]	NA	903
4	12:05	19.4	23.3	5.46	6.64	4	9	3.5	<0.1	2
5	12:10	20.7	59.9	8.37	7.16	4	9	3	0.2	28
6	12:15	19.9	66.6	3.26	7.13	9.00	<3	9.5	<0.1	7

[1]Because of sediment build-up in the system there was limited flow in sample location #2 and no flow in sample location #3. This prevented IEC from analyzing for chlorides and settleable solids at sampling location #2 and analyzing for any parameters at sampling location #3.

2.3 DISCUSSION OF WATER QUALITY RESULTS

This site was built to retain and detain water to reduce urban runoff during wet weather. The water that is flowing through this system is not being treated by chemical or physical means. Therefore it is not surprising that there is little change in the majority of the water quality results between the six sampling points, though there were some exceptions to this were spikes did occur. The next few paragraphs describe them.

Comparisons of site-specific results show a few noteworthy variations between monitoring locations and sampling events. For example, results from run #1 show a high reading for the chloride concentration at location #2 (Table 2A). Unfortunately, respective chlorides concentration values were not recorded/obtained [for this location] during runs #2 and #3. Sediment build-up at location #2 prevented the collection and analysis of samples and thereby, values were lacking for comparison purposes. Accordingly, the episodic concentrations of chlorides detected during run #1 may be attributable the high chlorine content of this sediment.

Also during the first run, the pathogen (fecal coliform and enterococcus) results at sampling location #3 were higher (≥24,000 mpn/100 ml) then the other sampling locations at the site. Unfortunately, because of sediment buildup in the system, this was the only event in which a sample was taken at sampling location #3. A potential explanation of the high bacterial numbers is that the detention crates (Sampling location #3) in addition to receiving the over flow from the subsurface cistern (Sampling location #1), received infiltration from the ground cover above it. It is possible that fecal material could have been at the ground and was carried in with the infiltration.

During Run #2 there were elevated temperatures at sampling locations #4, #5 and #6 as compared sampling location #1 (Table 2B). These three locations are all above ground and exposed to the elements. The sample taken from sampling location #5 has to flow through a hose. The sampling was performed in the afternoon of a sunny day; this is what IEC believed caused temperatures to be elevated. Also in run #2, there was a high reading in the turbidity concentration at location #5 that might have been caused by a buildup of solids in the hose connected from the play pump to the raised barrels (Table 2B). These solids might have been flushed through the system by the play pump.

Water quality results from the third sampling event show a spike in the turbidity at location #2 (Table 2C). This observation suggests the limited quantity of water in the reservoir from which the sample was recovered likely contained a high particulate/sediment concentration, which may have affected the turbidity reading at this monitoring location. In general, the intent and duality of the site design, combined with unforeseen issues, complicated systemic evaluation of the demonstration project with respect to water quality metrics. However, collectively, water quality datasets show a few discernable spatial and temporal differences between sampling locations that suggest spatial and temporal variability in terms of certain of physicochemical parameters.

It was the conclusion of both IEC and EDD that no correlation could be found between the water quality and water quantity portions of the project. The collated field data, collected over a relatively short period of time, did not demonstrate any substantial correlation between water quality measured in the system and water volume and flows through the system. Overall, comparative assessments verified that with limited field data, no definitive correlations could be derived to see any relationship between the different portions of the project. Nevertheless, the water quality results are presented in the attached Appendix A. Parameter-specific values are depicted [on both spatial and temporal scales] with respect to site location and sampling event.

3. WATER VOLUME MONITORING

The system was designed to perform two distinct functions: 1) To divert stormwater away from the City's combined sewer system for management within the site boundaries, and; 2) To store and deliver water to irrigate the garden spaces. In order to quantify the success of these functions, EDD installed water level monitoring devices at three points within the system. The first monitoring location is inside the subsurface cistern and records the water level in the cistern in one-inch increments at time intervals of ten minutes. The second monitoring location is located within the second of the six elevated barrels, where water level during pumping and irrigation is recorded. The third monitoring location is positioned just upstream of the infiltration galleries, and was intended to indicate only the presence or absence of water at that part of the system (i.e. to indicate whether the cistern is overflowing to the infiltration field). The sensor installed at this third monitoring location, however, has been operating suboptimally, due to sediment that accumulated in the vicinity during construction. A "tipping bucket" rain gauge was also installed at the site. The two water level loggers and the tipping bucket were connected to a datalogger that was accessed in the field using a laptop computer. Water levels were converted to volumes using the physical geometries of the cistern and barrel setups.

The cistern also receives flow from the underdrain of the pervious bluestone patio. The contribution from this source is not quantified because of limited monitoring capabilities, as well as the fact the flow from this source is delayed and reduced by infiltration.

3.1 WATER VOLUME RESULTS

Water levels (and computed volumes) were recorded successfully for a 55-day period between 9/3/10 and 10/27/10. This period included seven distinct rain events (two events occurred in separate bursts interrupted by brief dry periods). The events ranged in total depth between 2.5 and 55.3 mm and total duration between 0.5 and 9 hours. Peak (average) intensity was 65.9 mm/hour (see Table 3: Rain Event Data below). The seven events and the accompanying data are presented in Appendix B: Water Volume Monitoring Results - Figures 2A-2G. Each figure shows the precipitation recorded by the rain gauge (in one-hour increments), the computed water volume in the cistern and in the set of six elevated barrels. Also, superimposed over the cistern volume curve is a linear approximation of the rate of water level descent. These curves will be explained below.

Table 3. Rain Event Data

Rain Event	Date	Day	Total Storm Depth (mm)	Total Storm Volume (m3)	Storm Duration (hrs)	Average Intensity (mm/hr)	Antecedent Dry Period (days)
1A	9/12/2010	9	2.8	0.37	1	2.8	18
1B	9/13/2010	10	27.1	3.58	0.5	54.2	1
2	9/16/2010	13	33.0	4.36	0.5	65.9	2
3	9/27/2010	24	25.4	3.36	6.5	3.9	9
4A	9/30/2010	27	19.0	2.51	2	9.5	1
4B	10/1/2010	28	16.8	2.22	9	1.9	0
5	10/4/2010	31	2.5	0.33	5	0.5	3
6	10/11/2010	38	55.3	7.31	4	13.8	7
7	10/14/2010	41	12.6	1.66	6	2.1	1.5
Averages			21.6	2.86	3.8	17.2	4.7

3.2 DISCUSSION OF WATER VOLUME RESULTS

Each of the rain events recorded during the monitoring period elicited a rapid response in the cistern water level elevation. In cases when the incoming volume exceeded the available capacity in the cistern, the cistern elevation would peak (and in some cases remain at peak level for a period) and then rapidly decline as other subsurface void spaces become filled (ie: empty pipe, gravel substrate, infiltration gallery). The cistern level would then drop slowly as water stored inside it drains to the leach field and infiltrates, typically over a period ranging from 12 to 36 hours.

The extent of pumping of water from the cistern and use for irrigation influences the performance of the overall system. A pumping event appears in the data as a simultaneous drop in the cistern level and rise in the elevated barrel level. There are eleven events that fit this description. These events tend not to appear in Appendix B - Figures 2A-2G as they are performed during dry periods between storms. The pumping events can be seen in the full data series (Appendix C: Water Volume Monitoring - Data) and are listed below in Table 4: Likely Pumping Events and Likely Irrigation Events. After a pumping event occurs, however, the water level in the cistern returns to its previous value, indicating some undefined hydraulic connection either to the pervious pavement underdrain or to water stored in the pore spaces of the surrounding substrate.

Pumping events are generally followed by irrigation events which appear as drops in the water level in the above ground barrel system. There were twelve irrigation events in the first 23 days of the monitoring period. It is expected that pumping and irrigating will occur more frequently and in greater volumes in subsequent growing seasons. Since the gardens and irrigation system were installed late in the summer, demand for irrigation water was not fully established at the time of monitoring, and dropped off before the end of September.

Table 4. Likely Pumping Events and Likely Irrigation Events

Likely Pumping Events			Likely Irrigation Events		
	Drawdown			Drawdown	
Day	(in)	(m3)	Day	(in)	(m3)
1	1	0.063	1	2	0.074
4	1	0.063	2	1	0.037
5	2	0.126	4	2	0.074
7	1	0.063	5	2	0.074
8	1	0.063	7	1	0.037
10	1	0.063	8	1	0.037
11	1	0.063	10	1	0.037
12	1	0.063	11	1	0.037
17	1	0.063	12	1	0.037
21	1	0.063	17	1	0.037
22	3	0.189	18	1	0.037
			23	3	0.111
Totals		0.882			0.629

At the end of each rain event, the water level in the cistern slowly declined to the level of the overflow invert, or to a height of 38 cm above the cistern floor. After a short rain event, the decline was initially quite rapid and then slowed until draw-down was complete. During longer rain events there was no initial rapid decline, only a slow, consistent draw-down. This behavior supports the notion that overflow water from the cistern is first filling pore spaces within the piped connection to the infiltration galleries, the galleries themselves, and the gravel substrate that supports and surrounds the cistern. During larger events, collected water entering the system exceeded the storage capacity and caused surface overflows to the sidewalk/street/catchbasin/sewer system. After the pore spaces were filled, the rate of draw-down was slowed to the total rate of infiltration to the ground. The total effective infiltration area is not precisely known due to some sedimentation inside the detention crates. For this reason, no estimate can be made of the infiltration rate [L/T]. Instead, EDD generalized the draw-down by describing a volumetric infiltration rate or "rate of descent" of the water level in the cistern. These rates are approximated linearly and are reported below in Table 5: Stormwater Volume Monitoring and Analysis in units of m^3/day.

Table 5. Stormwater Volume Monitoring and Analysis

Rain Event	"Infiltration" Rate (Rate of Descent) (m3/day)	Available Detention Volume in Cistern (m3)	Hours at Capacity in Cistern	Total Draw-down Time (hours)	Infiltrated Volume (m3)	Percent Storm Infiltrated	Percent Storm Retained	Percent Storm Mitigated	Total Volume Mitigated (m3)
1A	0.195	0.518	0	21	0.26	69%	0%	69%	0.26
1B	0.471	0.581	0.7	11	0.13	4%	2%	6%	0.20
2	0.231	0.518	0.3	32	0.39	9%	0%	9%	0.39
3	0.281	0.715	5.8	45	0.55	16%	6%	22%	0.75
4A	0.302	0.518	5.7	22	0.27	11%	0%	11%	0.27
4B	0.258	0.282	12.6	54	0.66	30%	0%	30%	0.66
5	0.412	0.395	0.0	10	0.12	37%	0%	37%	0.12
6	0.282	0.518	0.3	31	0.38	5%	0%	5%	0.38
7	0.200	0.518	0	35	0.43	26%	0%	26%	0.43
Averages	0.292	0.507	2.8	29	0.353	23%	1%	24%	**3.44**
									13%

EDD speculated that the volumetric infiltration rate would correspond with the degree of saturation of the receiving soils prior to the onset of rain. To test this hypothesis EDD determined the antecedent dry period before each rain event, and plotted this against "infiltration." Appendix B: Figure 3: Infiltration vs. Antecedent Dry Period shows the results of this comparison, which does not confirm the hypothesis. If outlying points are removed, particularly those data involving very short rain events, the rate of "infiltration" appears somewhat constant, and does not increase with antecedent dry period. EDD stresses, however, that this hypothesis was tested with a very short period of data and suggest that additional studies be performed to test for this performance condition.

The constant volumetric rate of "infiltration" is used in further calculations to determine the total volume of "infiltration" for each storm. One can determine the total length of time between when the cistern first begins to overflow (exceeds 38 cm) and when it ceases to overflow (returns to original elevation), and assume that water is "infiltrating" during this entire period at the average rate described above. The total "infiltration" volume, therefore, is the product of the "infiltration" rate and the overflow period or draw-down time. The results of these calculations and the "Percent Storm Infiltrated" are shown in Table 5.

In some cases there was excess retention volume available in the cistern at the start of the rain event due to pumping of water for storage in the elevated barrels. This volume was isolated for its contribution to the total volume of water managed by the system during each event. Results of these calculations appear in Table 5 under "Percent Storm Retained."

Given the constraints of this project, EDD was unable to estimate the storage volume associated with soil pores in and around the GI system. This volume should also contribute to the total volume of water managed by the system, but it is omitted from the calculation. Rather, the sum of the Percent Infiltrated and Percent Retained becomes the "Percent Storm Mitigated" or the percent of the total captured volume that is prevented from reaching the combined sewer system. These values are underestimated because of the omission of the pore spaces.

Overall, the results show that 5-64% of the total incident storm volume was infiltrated; 0-6% were retained/reused; suggesting that the net effect of the entire GI pilot project was to mitigate, or reduce runoff from the project site (including its offsite catchment areas) by 5-64%.

4. CONCLUSIONS

The stormwater management system constructed at 368 13th Avenue in Newark captures rainwater from 135 m^2 of adjacent roof areas and 25 m^2 pervious bluestone paving, diverting a portion of it from the existing combined sewer system. Depending on individual storm characteristics and antecedent irrigation practices and dry period duration, this GI facility can reduce stormwater runoff generated from this site by 5-64%. During the monitoring period, approximately 13% of the total captured storm volume was prevented from reaching the sewers and contributing to combined sewer overflows. This figure, however, is underestimated due to the following circumstances which must be considered in any final analysis of system effectiveness. Firstly, the system was designed to provide stored water for irrigation of garden areas within the site. However, as construction was completed late in the growing season, there was little demand for irrigation water resulting in reduction of overall efficiency. Had there been greater irrigation demand, more water retained in the cistern would have been pumped to the elevated barrels thus providing more volume for storage of the subsequent rain event. Secondly, a breach in the subsurface connections with the infiltration gallery appears to have caused extensive sediment buildup within the gallery, thus reducing the infiltration capacity of the leach field. Despite these uncertainties, the stormwater management system appears to operate as designed, providing water for irrigation of the gardens and reducing runoff from the site, a precursor to reducing local combined sewer overflow.

Project performance goals were to provide water for irrigation and to detain water from reaching the combined sewer system. The results of the water quality and water volume monitoring demonstrate that the system more directly influenced discharge volume than water quality. Although fundamental components of the study were to construct and evaluate a network of GI measures to reduce urban runoff from the site during wet weather, the system was not designed to treat water flowing through the system by chemical or physical means. Therefore, it is not surprising that there is little change in the majority of the water quality results between the six sampling points. Future designs could include treatment/filtration components that improve water quality prior to discharge. This would increase demand on project space and cost.

The breaches in the system and the subsequent uncertainties introduced into the monitoring scheme may be due to the use of an open-bottom chamber (StormChamber) wrapped in a pond liner that served as the cistern. The open bottom allowed for greater settling of the cistern and compromised plumbed connections to the remaining portions of the system.Additionally, it is presumed that sediment found to occupy the infiltration galleries was deposited during an extended construction period when stockpiles of soil were left near monitoring wells and open trenches. The original schedule for the garden called for construction to be completed over a two or three month span. GNC's final construction period was approximately 15 months. While the extended period benefitted stewardship and job training goals, it was not possible to provide full time construction administration for the LID components. No further sedimentation is expected as construction is now complete. There is a clean out sump upstream of the cistern that will be maintained by GNC. GNC is responsible for all maintenance of the sight in perpetuity.

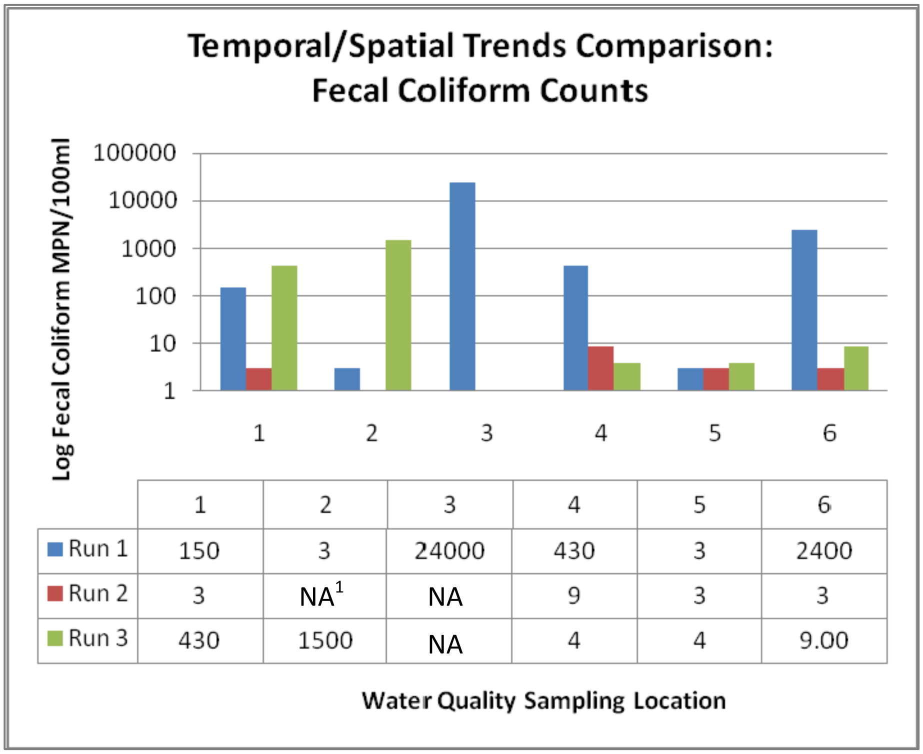
It is not intended that the sedimentation issues be repaired in the system, which appears to be operating correctly (though perhaps not optimally), despite the presence of sediment and breaches in the connections. The primary dysfunction lies in the inability to fully and accurately monitor system flows because of the uncertainties introduced by the breaches.

Ideally, future designs would also follow more closely local detention guidelines for new development sites. Because this pilot design was a collaborative process between the community and not-for-profits, space was a limiting commodity at the site. The design team sought to maximize detention, retention (reuse) and infiltration to the greatest extent possible while maintaining a community oriented design and providing training and educational opportunities. It is not clear at this time that any of the system components are sized inadequately to meet the needs of the site. The complications in installation that led to reduced storage volumes (settling of cistern and sediment buildup within the infiltration galleries) in the final system can be avoided in the future.

As with any community oriented project, there is a universal issue of balance between involving a broad base of stakeholders and meeting technical goals. This project execution was highly successful in providing skills training to several dozen recently incarcerated members of the community, and involving input from students, staff and parents from the public school across the street as well as unaffiliated neighbors. As these goals were a priority, some compromises in the construction timetable became inevitable, and some flaws in the system installation were introduced. In the future, a shorter construction period with more field supervision would likely improve the chances of more precisely meeting the project design goals.

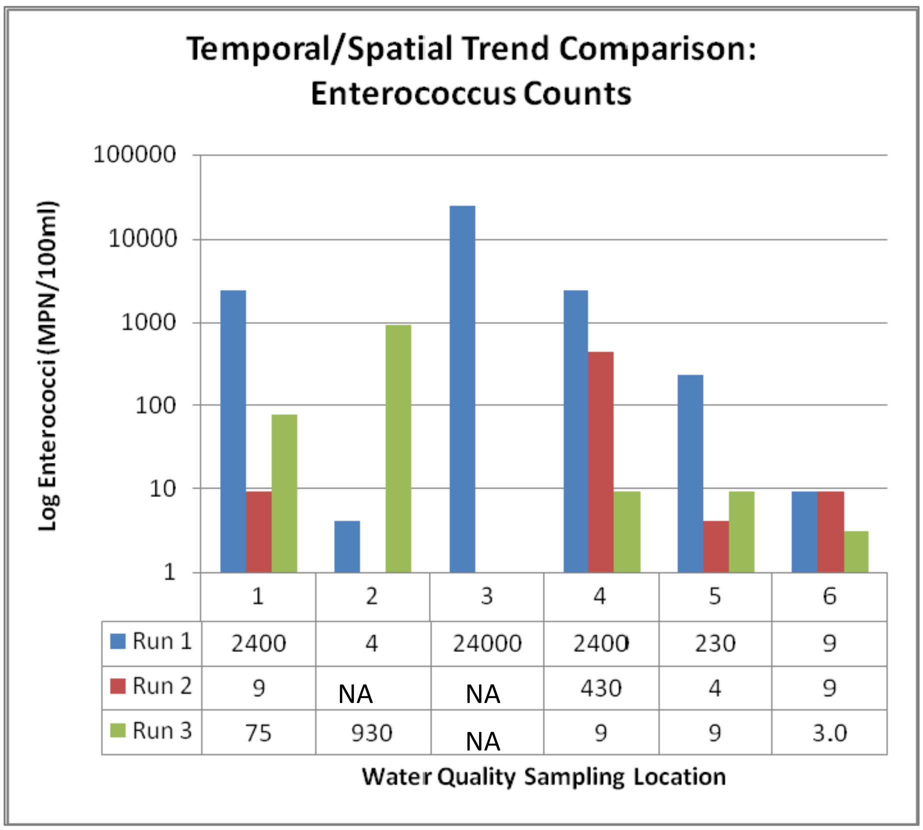
Indeed, community members visiting the site and utilizing its services provided resounding reviews. Gardeners were quite happy to have unlimited access to water for irrigation, and enthusiastic lines formed to use the treadle pump. Classes from the school came over to participate during and post-construction. Neighbors using the garden provided feedback that the space was innovative and active – not only an urban oasis, but space with opportunities for education and participation.

APPENDIX A: WATER QUALITY MONITORING: RESULTS AND DATA



	1	2	3	4	5	6
Run 1	150	3	24000	430	3	2400
Run 2	3	NA[1]	NA	9	3	3
Run 3	430	1500	NA	4	4	9.00

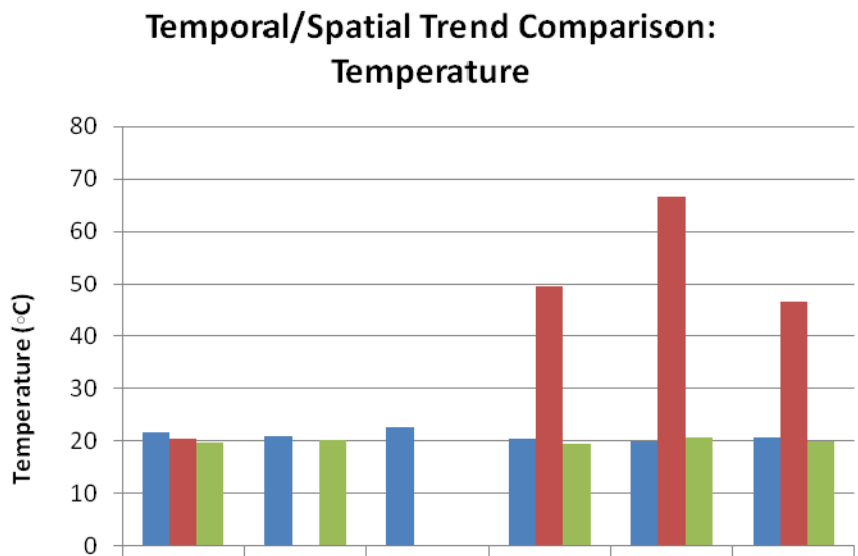
Figure 1A. Temporal/Spatial Trends Comparison: Fecal Coliform Counts



	1	2	3	4	5	6
Run 1	2400	4	24000	2400	230	9
Run 2	9	NA	NA	430	4	9
Run 3	75	930	NA	9	9	3.0

Figure 1B. Temporal/Spatial Trends Comparison: Enterococcus Counts

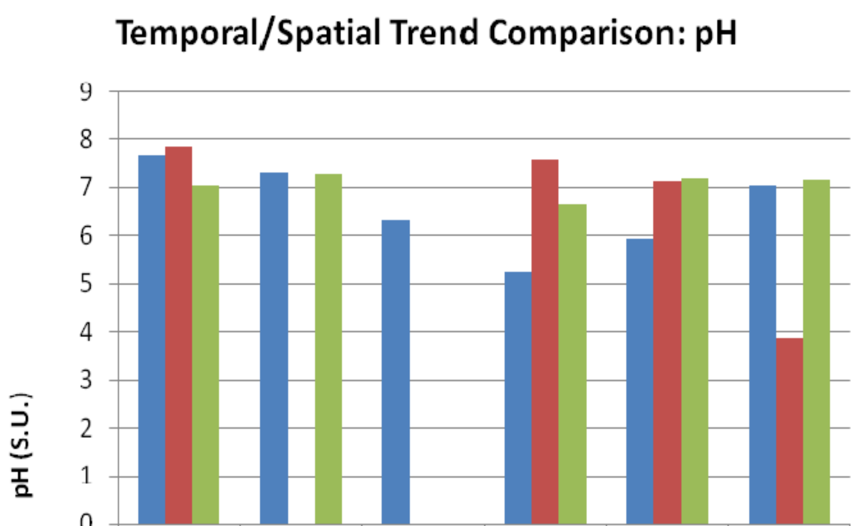
[1]NA indicates sediment build-up prevented sample collection and analysis.



	1	2	3	4	5	6
Run 1	21.6	20.8	22.7	20.5	20.0	20.6
Run 2	20.5	NA[1]	NA	49.4	66.7	46.4
Run 3	19.6	20.2	NA	19.4	20.7	19.9

Water Quality Sampling Location

Figure 1C. Temporal/Spatial Trends Comparison: Temperature



	1	2	3	4	5	6
Run 1	7.65	7.33	6.29	5.23	5.93	7.04
Run 2	7.84	NA	NA	7.58	7.11	3.85
Run 3	7.03	7.27	NA	6.64	7.16	7.13

Water Quality Sampling Location

Figure 1D. Temporal/Spatial Trends Comparison: pH

[1] NA indicates sediment build-up prevented sample collection and analysis.

Table 1A.Metal Analysis Results-Run 1

Metal	Sample Location #1	Sample Location #2	Sample Location #3	Sample Location #4	Sample Location #5	Sample Location #6
Ag	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L
Al	<27.7 µg/L	<27.7 µg/L	589 µg/L	<27.7 µg/L	43 µg/L	<27.7 µg/L
As	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L
Be	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L
Cd	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L
Co	<6.15 µg/l	<6.15 µg/l	<6.15 µg/L	<6.15 µg/L	<6.15 µg/L	<6.15 µg/L
Cr	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L
Cu	23.9 µg/L	36.4 µg/L	145 µg/L	33.3 µg/L	94.5 µg/L	159 µg/L
Fe	213 µg/L	317 mg/L	542 µg/L	10.4µg/L	56.6 mg/L	559 µg/L
Mn	38.8 µg/L	118 µg/L	19.5 µg/L	<13.3 µg/L	324 µg/L	78.2 µg/L
Mo	13.5 µg/L	<12.5 µg/L	<12.5 µg/L	<12.5 µg/L	<12.5 µg/L	<12.5 µg/L
Ni	55 µg/L	<10.8 µg/L	<10.8 µg/L	33.4 µg/L	30.4 µg/L	32 µg/L
Pb	25 µg/L	<20.6 µg/L	<20.6 µg/L	<20.6 µg/L	253 µg/L	<20.6 µg/L
Sb	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L
Se	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L
Tl	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L
V	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L
Zn	49.7 µg/L	78.9µg/L	56.2 µg/L	36 µg/L	860 µg/L	439 µg/L

Table 1B. Metal Analysis Results-Run 2

Metal	Sample Location #1	Sample Location #4	Sample Location #5	Sample Location #6
Ag	16 µg/L	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L
Al	146 µg/L	<27.7 µg/L	23.3 µg/L	29.0 µg/L
As	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L
Be	<6.5 µg/L	<6.5 µg/L	<6.5 µg/L	<6.5 µg/L
Cd	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L
Co	<6.15 µg/L	<6.15 µg/L	<6.15 µg/L	<6.15 µg/L
Cr	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L
Cu	31.0 µg/L	40.6 µg/L	213 µg/L	166 µg/L
Fe	756 µg/L	190 µg/L	10.6 mg/L	954 µg/L
Mn	88.9 µg/L	NR-saturated	292 µg/L	75 µg/L
Mo	<12.5 µg/L	<12.5 µg/L	<12.5 µg/L	<12.5 µg/L
Ni	<10.8 µg/L	34.0 µg/L	29.7 µg/L	32.2 µg/L
Pb	16.8 µg/L	31.9 µg/L	437 µg/L	25.8 µg/L
Sb	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L
Se	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L
Tl	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L
V	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L
Zn	86.1 µg/L	87.5 µg/L	3.83 mg/L	354 µg/L

Table 1C. Metal Analysis Results-Run 3

Metal	Sample Location #1	Sample Location #2	Sample Location #4	Sample Location #5	Sample Location #6
Ag	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L	<6.40 µg/L
Al	74.0 µg/L	5.61 mg/L	<27.7 µg/L	18.6 µg/L	<27.7 µg/L
As	<18.8 µg/L	<18.8 µg/L	<18.8 µg/L	38.5 µg/L	<18.8 µg/L
Be	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L	<6.50 µg/L
Cd	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L	<7.40 µg/L
Co	<6.15 µg/l	9.0 µg/L	<6.15 µg/L	<6.15 µg/L	<6.15 µg/L
Cr	<7.20 µg/L	12.1 µg/L	<7.20 µg/L	<7.20 µg/L	<7.20 µg/L
Cu	41.3 µg/L	416 µg/L	110 µg/L	134 µg/L	51.3 µg/L
Fe	363 µg/L	6.60 mg/L	205 µg/L	2.94 mg/L	469 µg/L
Mn	50.7 µg/L	335 µg/L	16.3 µg/L	104 µg/L	19.3 µg/L
Mo	<12.5 µg/L	<12.5 µg/L	<12.5 µg/L	35.7 µg/L	<12.5 µg/L
Ni	34.6 µg/L	48.1 µg/L	36.4 µg/L	74.4 µg/L	34.3 µg/L
Pb	<20.6 µg/L	169 µg/L	54.3 µg/L	<20.6 µg/L	25.7 µg/L
Sb	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L	<39.8 µg/L
Se	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L	<37.4 µg/L
Tl	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L	<34.8 µg/L
V	<6.90 µg/L	15.7 µg/L	<6.90 µg/L	<6.90 µg/L	<6.90 µg/L
Zn	72.5 µg/L	681 µg/L	81.7 µg/L	1.17 mg/L	164 µg/L

APPENDIX B: WATER VOLUME MONITORING: RESULTS

Figure 2A. Event 1 – Days 9-11

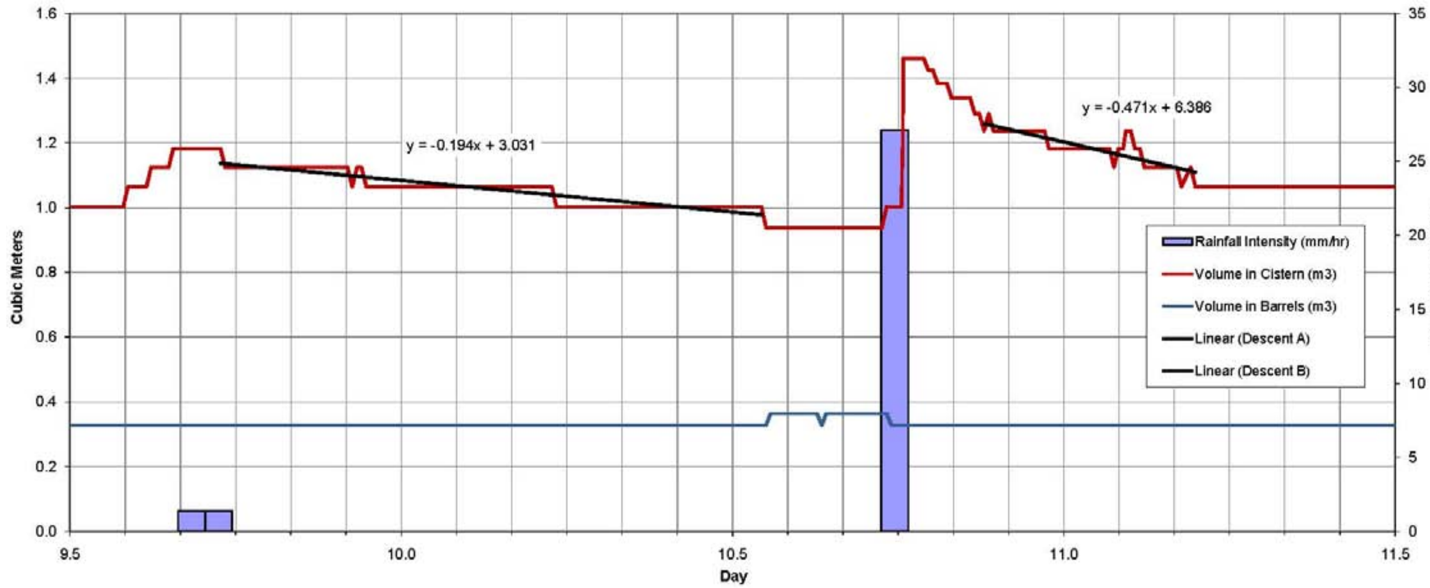


Figure 2B. Event 2 – Days 13-15

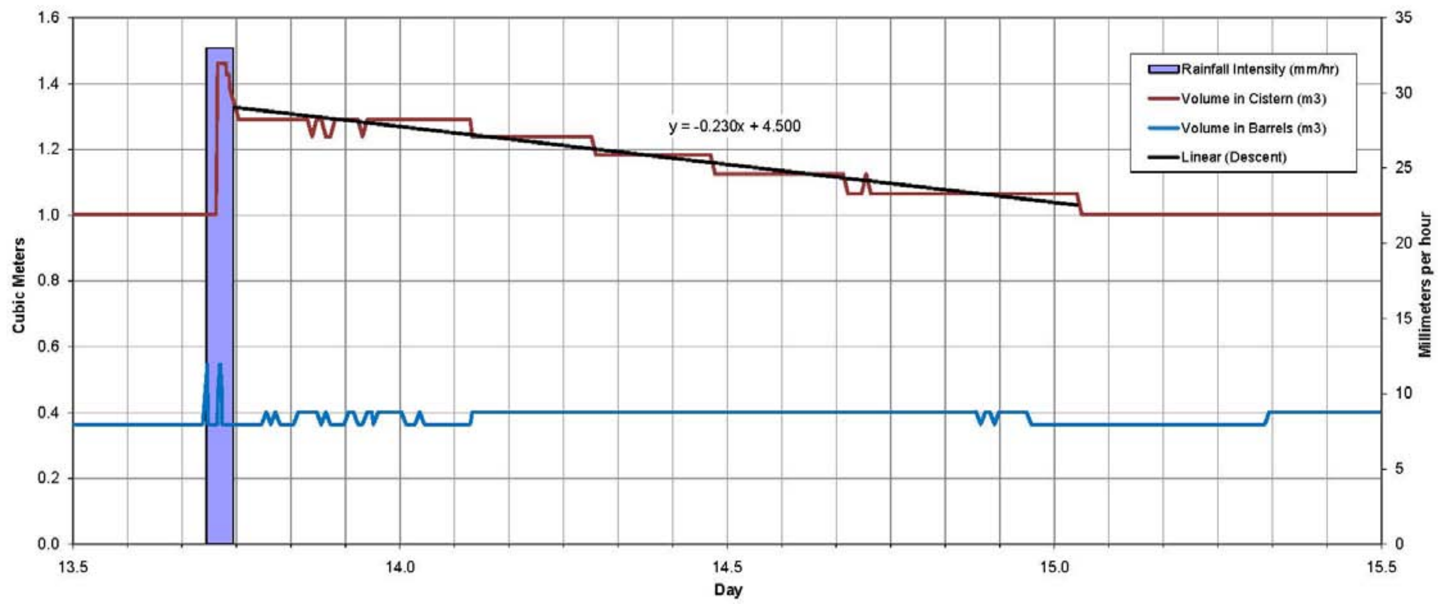


Figure 2C. Event 3 – Days 24-26

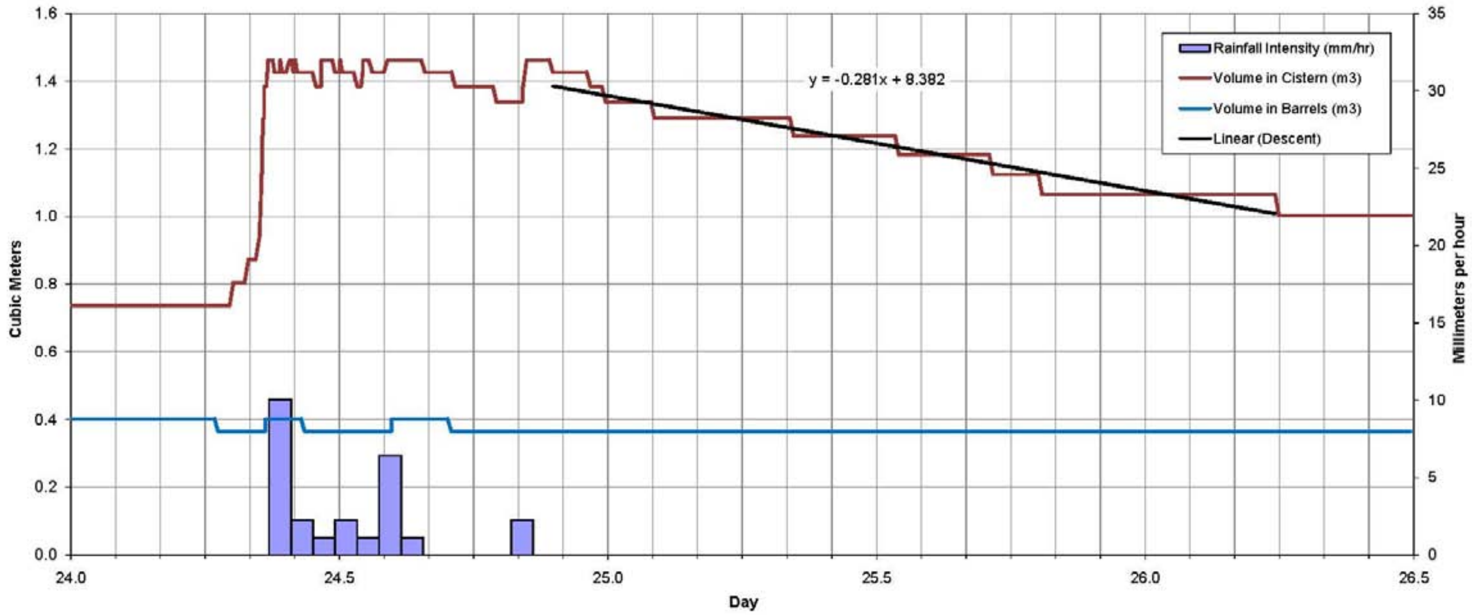


Figure 2D. Event 4 – Days 27-30

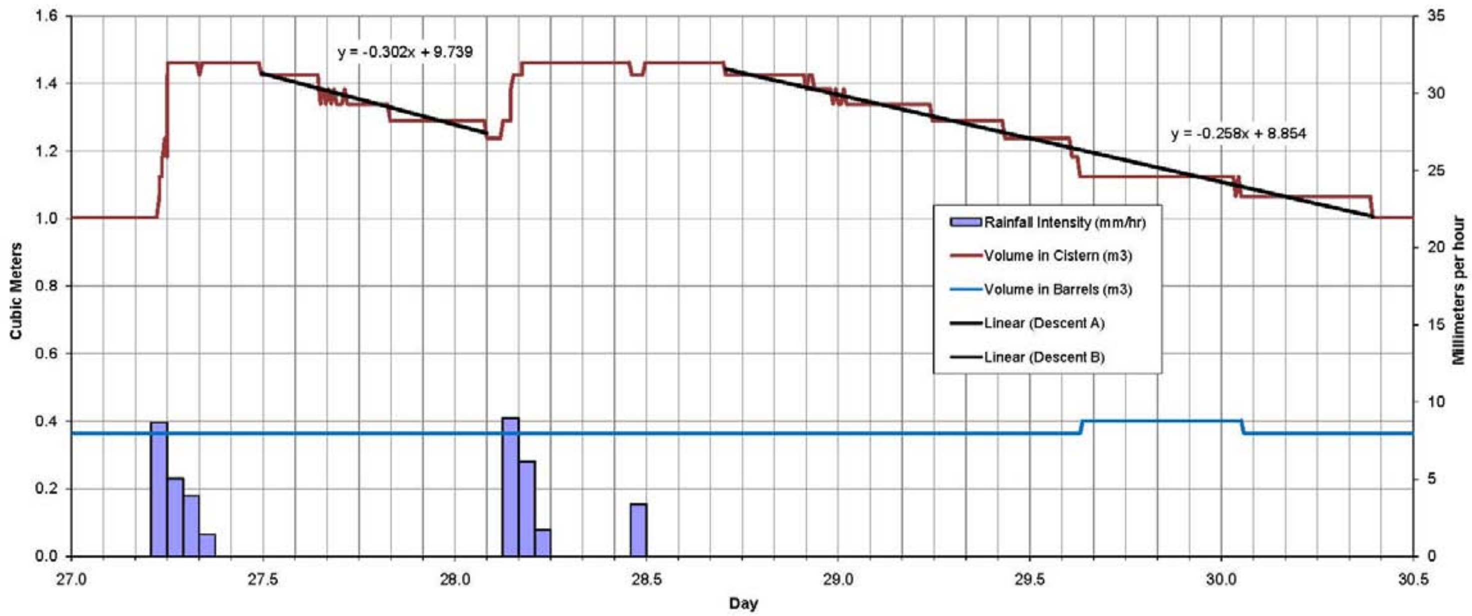


Figure 2E. Event 5 – Day 31

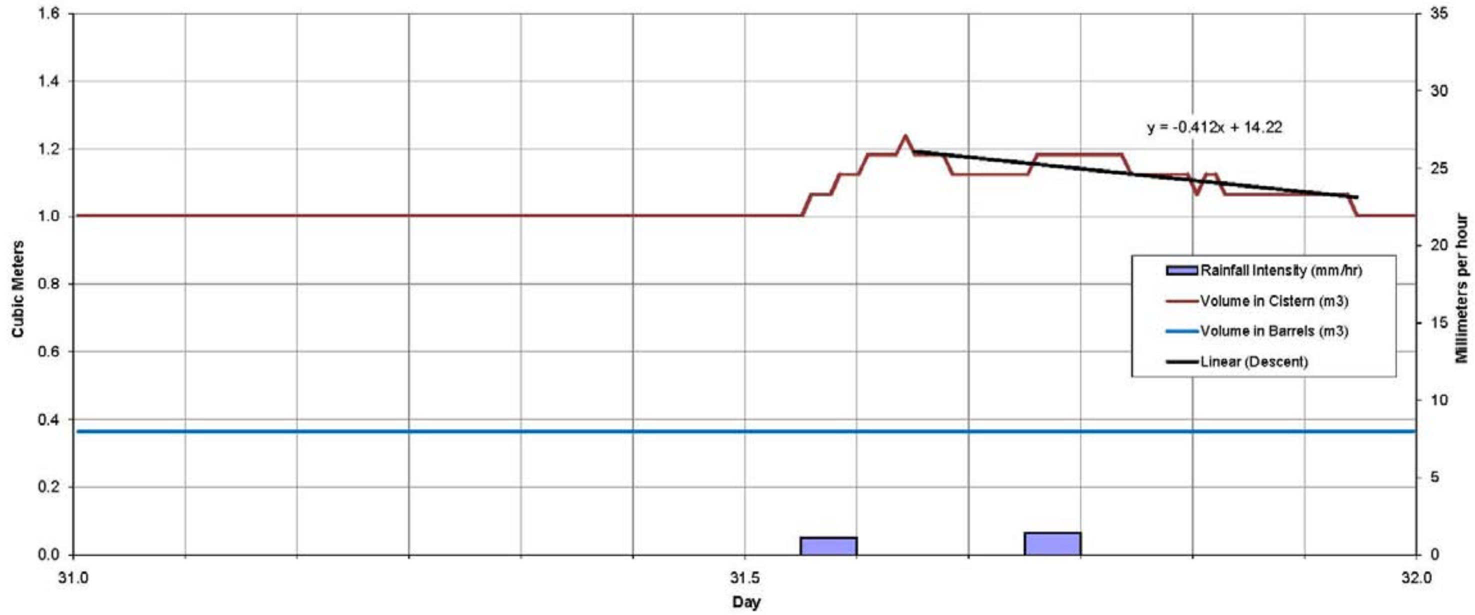


Figure 2F. Event 6 – Days 38-40

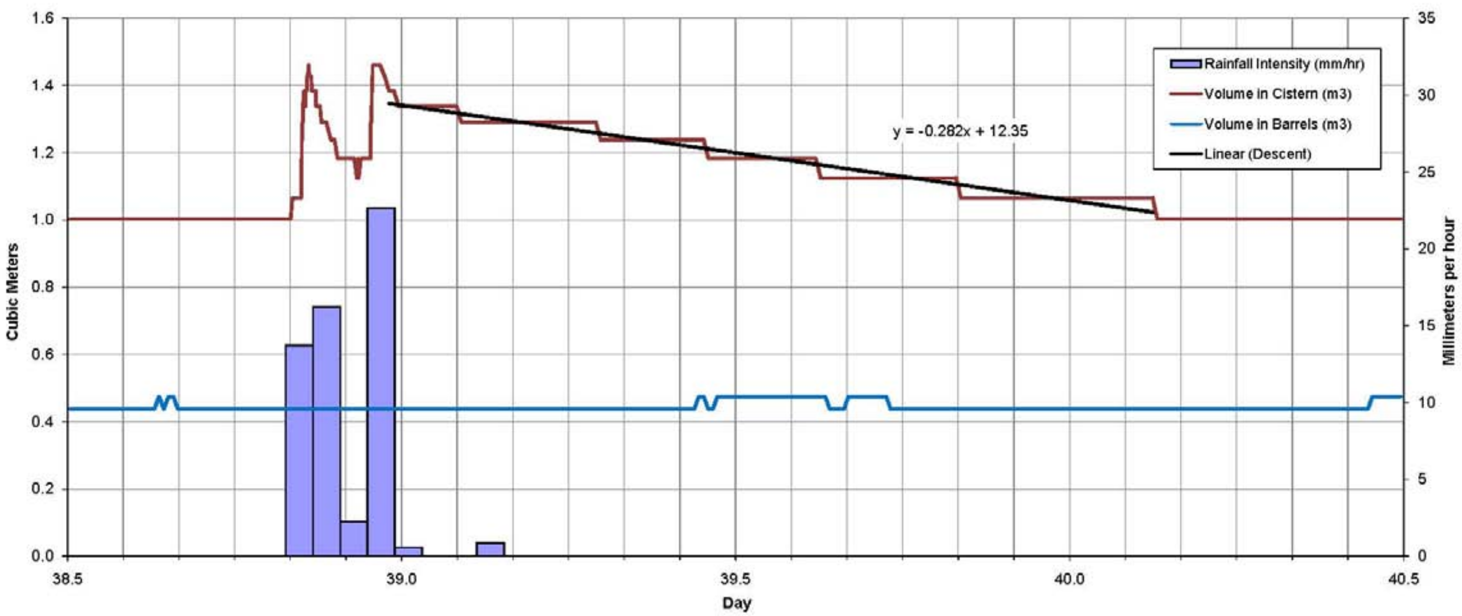


Figure 2G. Event 7 – Days 41-43

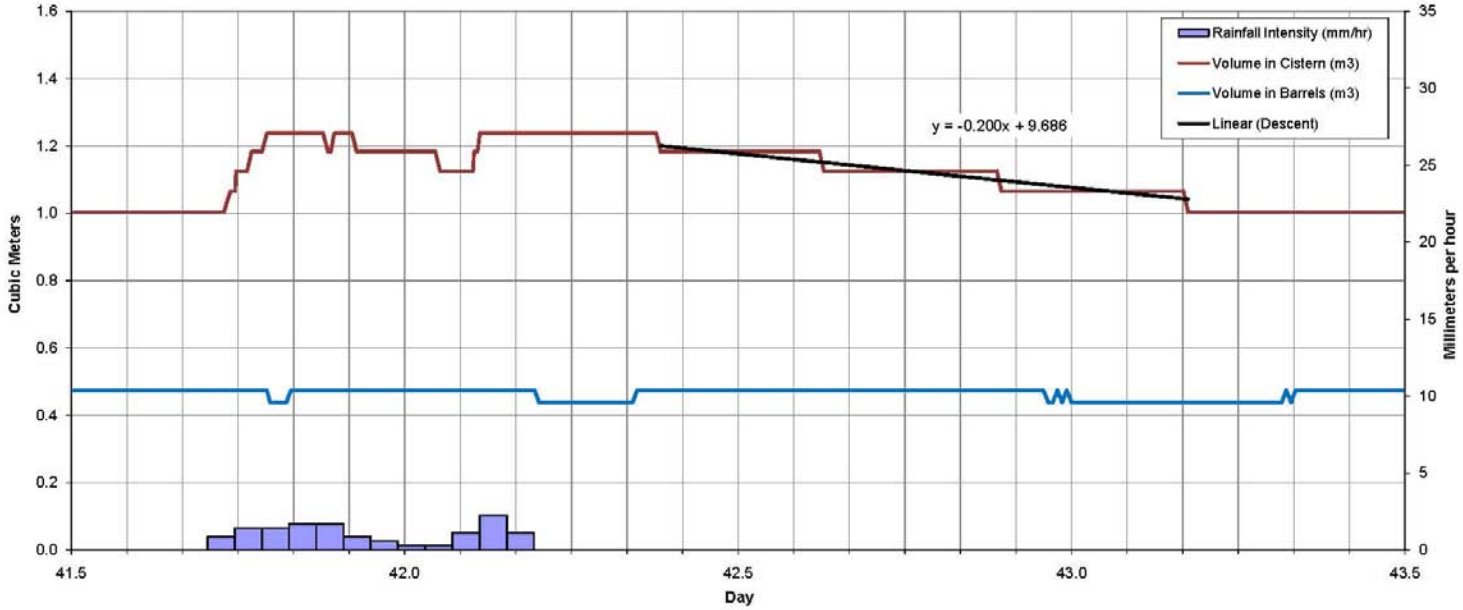
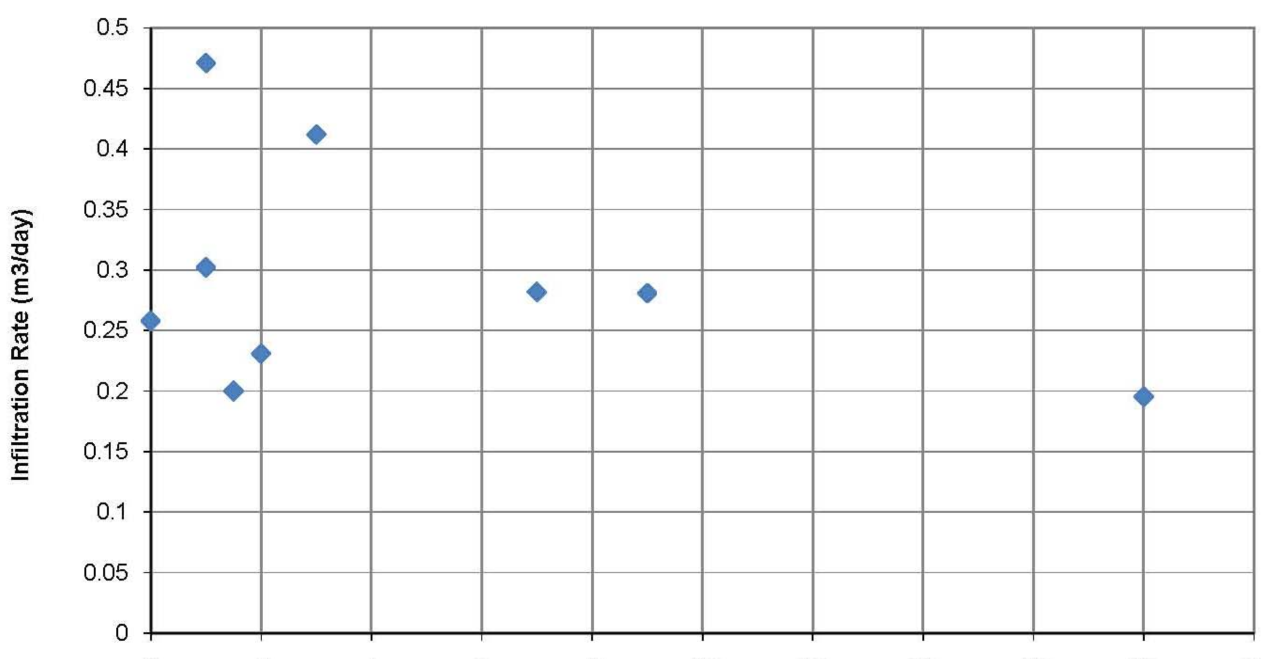
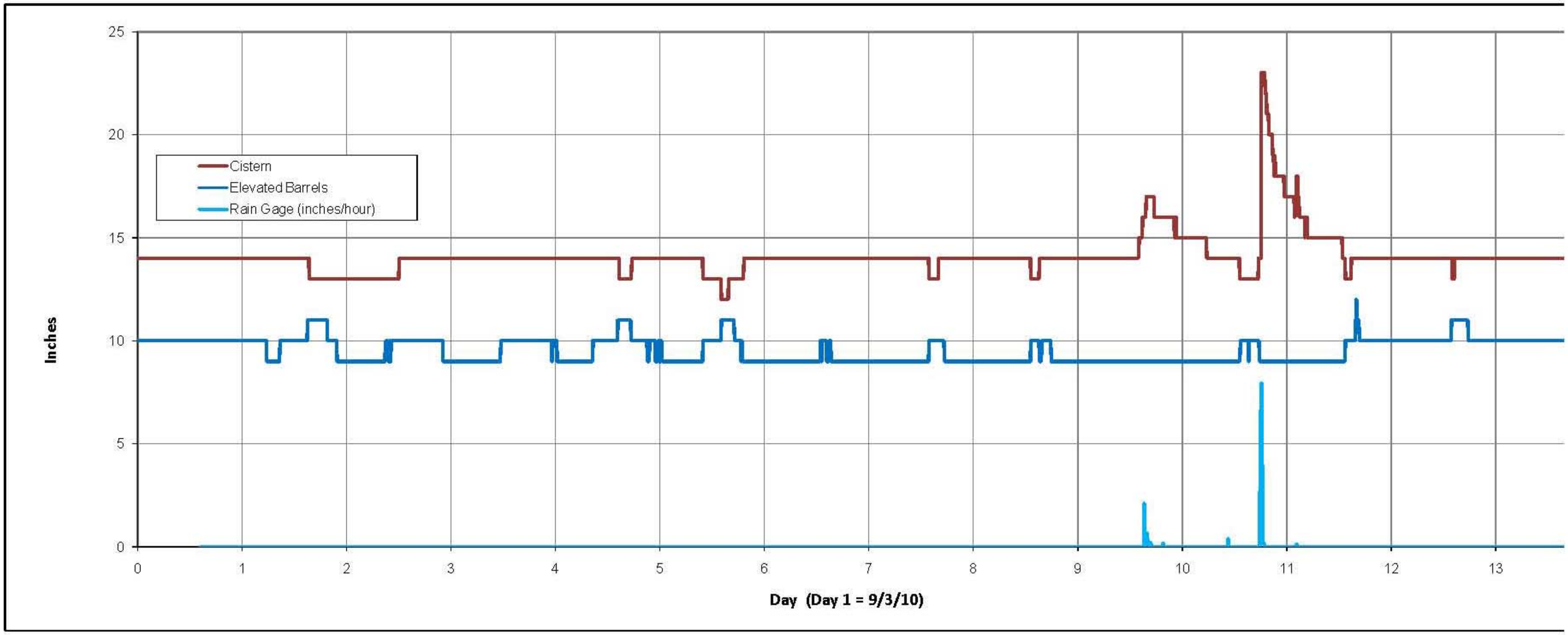


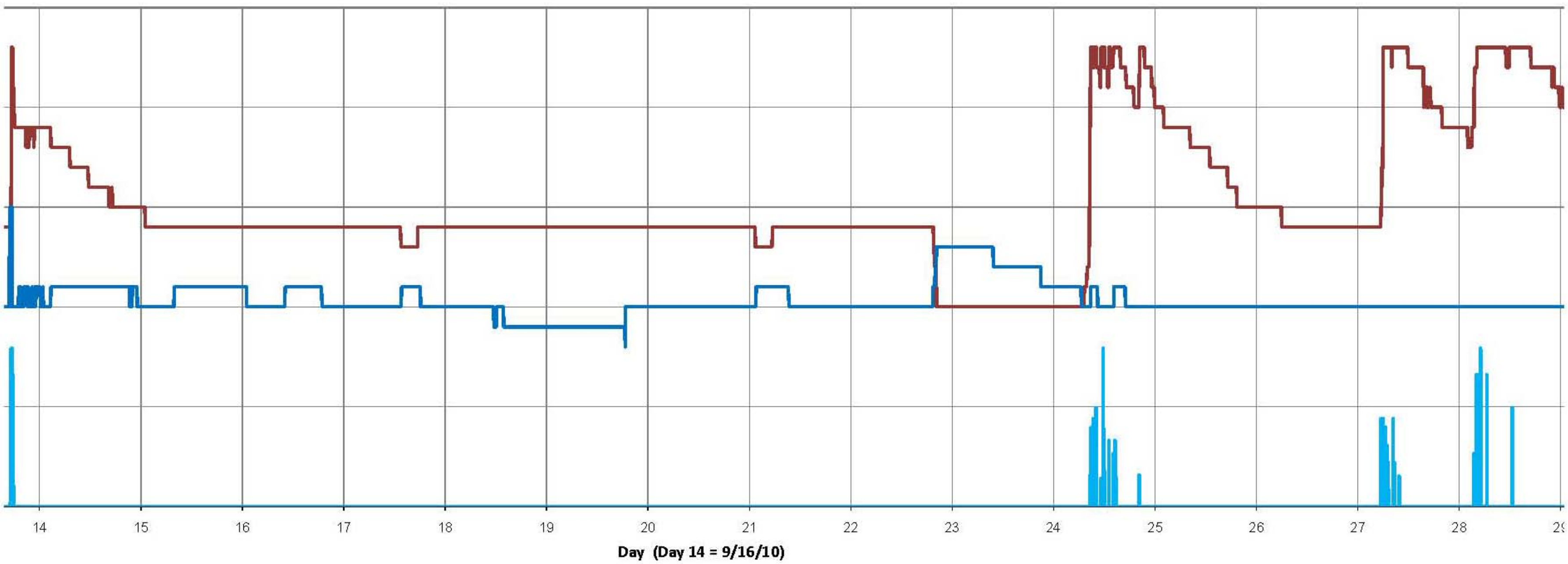
Figure 3. Infiltration Vs. Antecedent Dry Period



APPENDIX C: WATER VOLUME MONITORING: DATA

APPENDIX C: FULL DATA SERIES (page 1)




14
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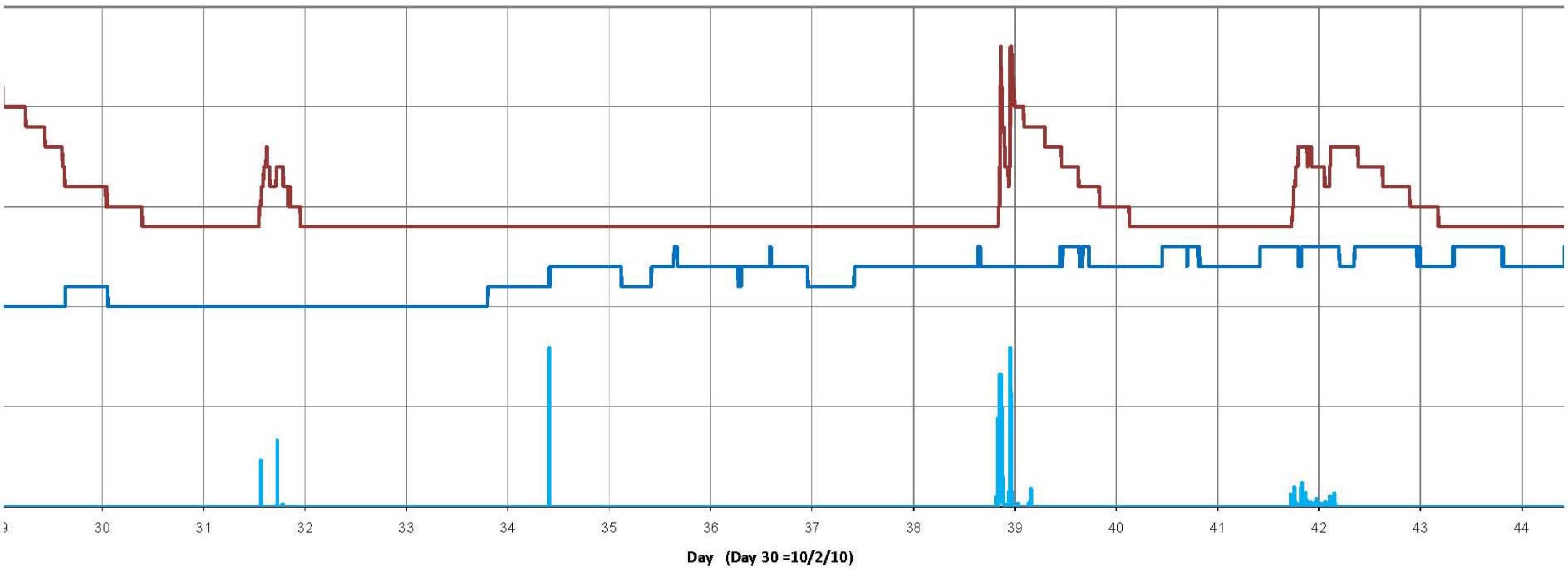
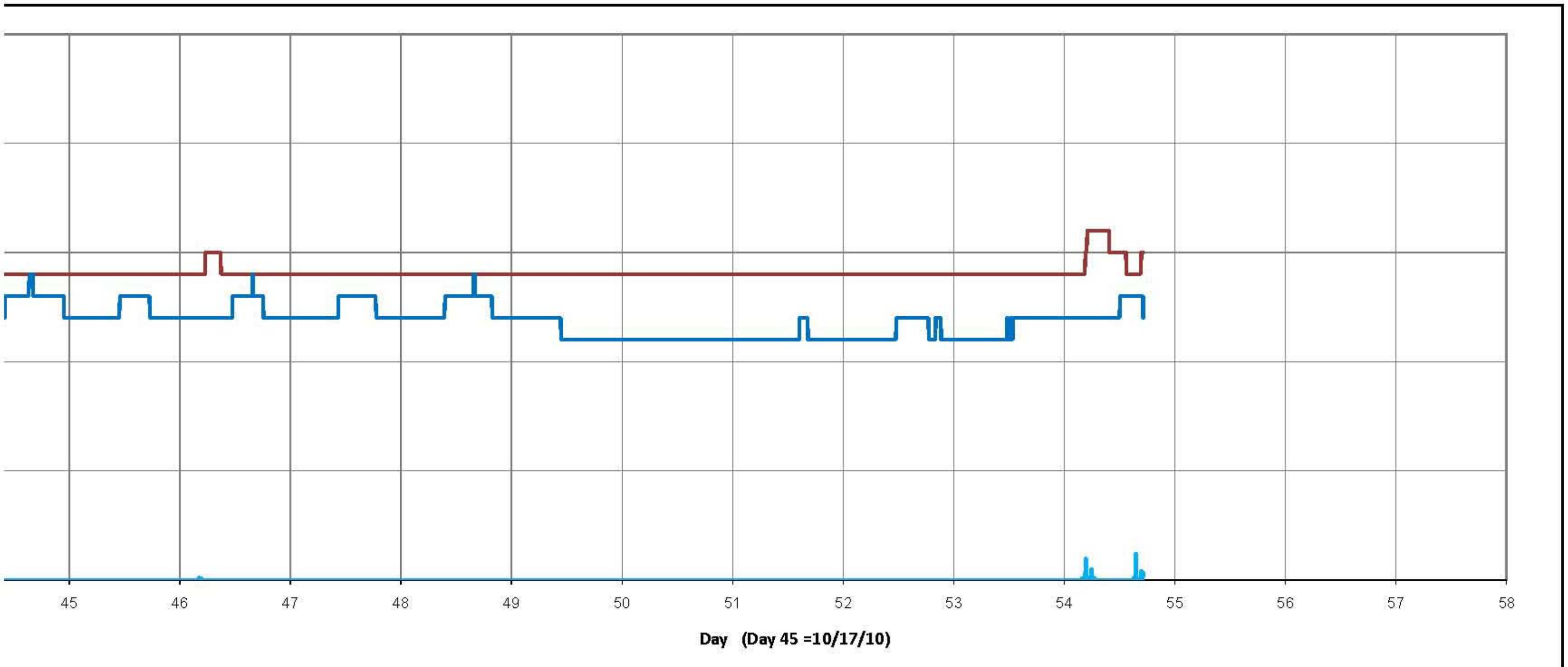
Day (Day 14 = 9/16/10)

APPENDIX C: FULL DATA SERIES (page 3)



APPENDIX C: FULL DATA SERIES (page 4)



APPENDIX D: DETAILED PROJECT TIMELINE

January - March 2009

- Kick-off meeting with stakeholders
- Selection of site
- Design charrettes with community members

Spring 2009

- Final design presented to community

Summer 2009

- Construction of garden commences

December 2009 – March 2010

- Construction halts over winter. Construction delays lead to postponing monitoring.

Spring 2010

- Construction of garden resumes; the subsurface retention and detention tanks and all subsurface pipes were completed.

Summer 2010

- Construction of garden completed; all green infrastructure technologies were installed mid-July with monitoring systems up and running in late August, 2010.

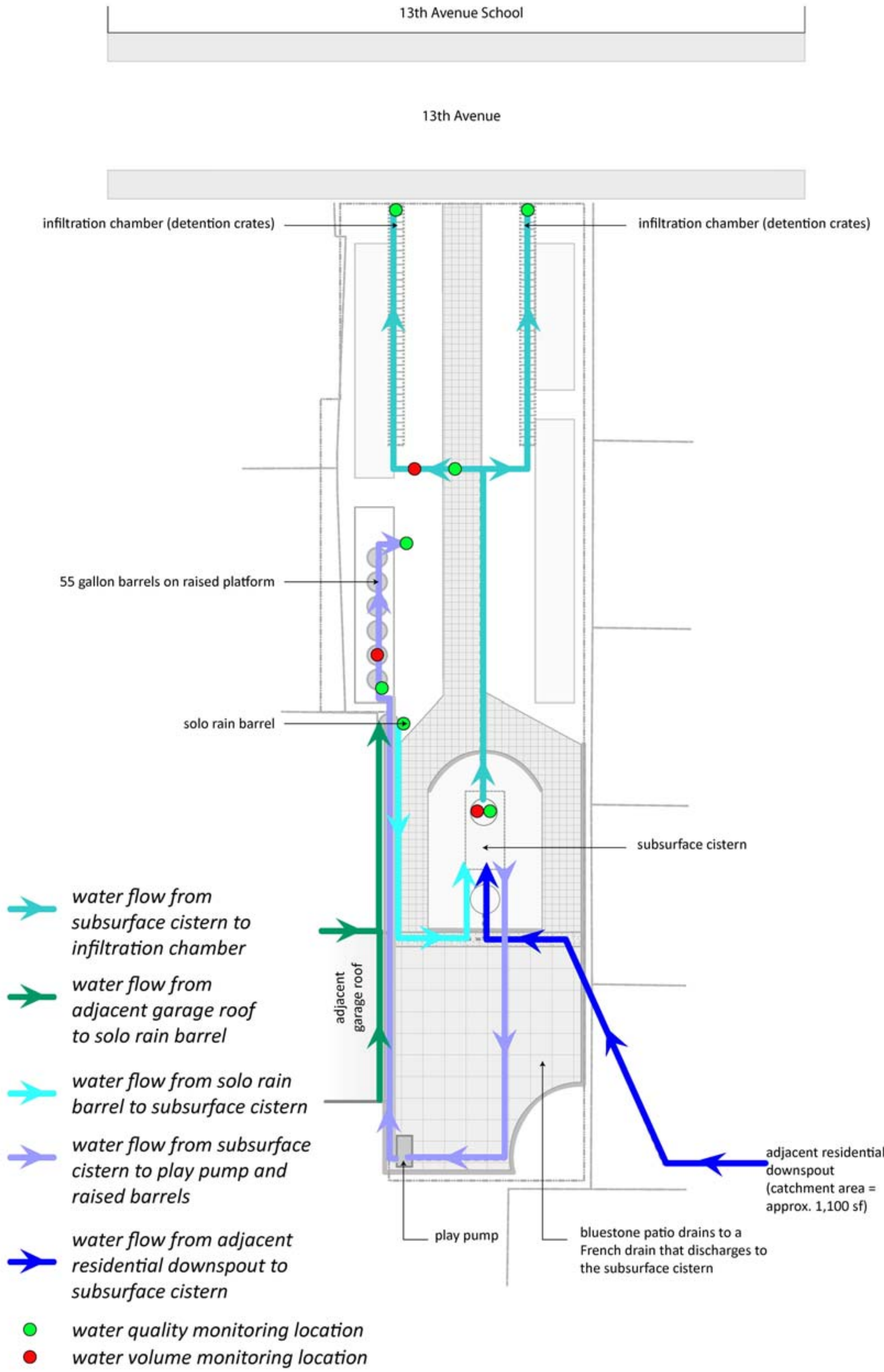
August - October 2010

- Water quality and quantity sampling period.

December 31, 2010

- IEC/EDD joint final report submitted.

APPENDIX E: WATER FLOW SCHEMATIC



APPENDIX F: SITE PHOTOS

1. March, 2009 | Site After Clearing, but Before Construction

2. July, 2009 | Installation of Subsurface Cistern

3. July, 2009 | Installation of adjacent residential downspout

4. July, 2009 | Installation of French drain

5. August, 2009 | Installation of infiltration galleries

6. October, 2009 | Installation of permeable paver walkway

7. April, 2010 | Installation of raised planting beds and barrel platform

8. August, 2010 | Operation of treadle play pump

9. August, 2010 | Raised barrel platform

10. August, 2010 | Garden completed

11. August, 2010 | Community gardener utilizing reuse water