FINAL REPORT v11-11-13

Texas Nonpoint Source Management Program
McAllen Innovative Storm Water Detention Facilities
Contract 582-9-77095

Project Team:
Kim D. Jones
Abel Garza
Vinod Balakrishnan
Jingyi Zhang
Ayokunle Falade
Adetayo Adeniyi

Executive Summary

This project had as its objective implement and evaluate innovative stormwater detention facilities (RDFs)/green space systems in the City of McAllen, Texas located in and around the Arroyo Colorado watershed. Two RDFs with different designs and structural enhancements were compared and contrasted and performance data on flow reduction and nutrient and water pollutant were collected. The McAuliffe RDF was a basin with a slope toward the western edge of the RDF which resulted in two permanent ponds for storage and water retention. During the course of the project a weir that channels inlet flow over a microsreen structure was constructed at the inlet to the RDF, and a small channel wetland was created just before the RDF outlet at McAuliffe. Unfortunately, the total microscreen structure was not completed until a few months before the end of the project, preventing planned monitoring to determine its effectiveness. The Morris Middle School RDF was a dry basin with a small channel running through the approximate center of the facility. Except for storm events, the Morris facility was largely dry and barren of water. A small constructed wetland was excavated to a shallow groundwater table in the center of the RDF as an enhancement. At the much smaller Dog Park stormwater retention facility, a rock filter was installed around the outside of a concrete riser structure and inlet and outlet slots were cut in the walls to channel surface water behind the riser and through the filter and then into an outlet pipe at the bottom of the riser. The concept was to create some attached growth biomass on the wet rock and partially treat the inlet water as it travels through the filter. Overall this project demonstrated that during the relatively dry years of 2011, 2012 and 2013, a combination of the data collected for both sampled and unsampled flow reduction events can be used to estimate that the two RDF structures have removed a total of 618 lbs. of NO2-NO3, 981 lbs. of TKN, 1,474 lbs. of TN, 447 lbs. of TP, 364 tons of TSS, 19,437 lbs. of BOD and 2×10^{12} *E.coli* (MPN) bacteria. It is clear that enhancement to the large detention and retention system basins in parts of the Rio Grande and Arroyo Colorado watershed can offer significant flow and pollutant reduction when applied in different areas. The basin design at McAuliffe with a set of permanent ponds for retention appears to be more efficient than the commonly dry basin at the Morris Middle School for removing most pollutants. The stormwater wetland at Morris probably helps remove nutrients but it can be easily bypassed during large events.

Contents

List of Tables…………………………………………………………………………...3
List of Figures……………………………………………………………………………4
1. Introduction..5
1.1. Project Objectives 5
1.2. Site description and drainage characteristics 6
1.2.1. McAuliffe Elementary School Regional Stormwater Detention Facility (RDF)............6
1.2.2. Morris Middle School RDF 12
1.2.3. McAllen Dog Park 14
2. Methodology 16
2.1. Water Sampling and Flow Measurements 16
2.1.1. Sampling Process Design – McAuliffe RDF 16
2.1.2. Sampling Procedures for the Morris RDF 18
2.1.3. Sampling procedure for McAllen Dog Park 18
2.2. Quality Control Techniques – for flow data 19
2.2.1. Velocity Signal Strength 19
2.2.2. Velocity Spectrum Strength 19
2.2.3. Spectrum Ratio...20
2.3. Equipment and software 20
2.3.1. Overview of flow monitoring equipment 20
2.3.2. ISCO 2150 Flow Module..21
2.3.3. Teledyne ISCO 6712 Portable Sampler...22
2.3.4. Data Transmission – ISCO 2105c Modem Module...23
2.4. Overview of Flowlink software 23
2.5. Volume flow reduction calculation procedure and data validation 24
2.5.1. Flow reduction calculation...24
2.6. Nutrient load reduction calculations 26
3. Results and discussion of flow and nutrient data collection and analysis for the RDFs and rock filter BMP 29
3.1. Categorization of stormwater runoff events and performance at Regional Stormwater Detention Facilities (RDFs). 29
3.2. Flow reduction analysis 30
3.2.1. Flow reduction (Peak to Peak –P2 - method) 30
3.2.2. Correlation analysis between total inflow volume and flow reduction 39
3.3. RDF Nutrient load reduction analysis...40
3.3.1. Nutrient load reduction analysis for events with composite sampling. 40

3.3.2. Nutrient and bacteria load reduction estimation in storm events without composite sampling ... 46
3.4. Load Reduction estimation for all of the 2011-2012 events ... 48
References ... 51
Appendix A ... 52
Appendix B ... 53

List of Tables

Table 2-1. Sampling interval for McAuliffe inlet auto sampler 17
Table 2-2. Sampling interval for McAuliffe outlet autosampler 18
Table 2-3. Equipment and software used in McAllen RDFs 20
Table 2-4. Data for an example calculation of nutrient reduction during a stormwater runoff event at the Morris RDF 27
Table 3-1. Qualified storm runoff events at McAuliffe RDF, McAllen , Texas (2011-2013) 31
Table 3-2. Qualified storm runoff events at Morris RDF, McAllen, Texas 31
Table 3-3. Summary of flow reduction analysis using P2 method for the McAuliffe Elementary School RDF. 33
Table 3-4. Storm events classified by type (intensity) at McAuliffe RDF. 34
Table 3-5. Summary of flow reduction using the graphical P2 method for Morris Middle School RDF. 36
Table 3-6. Storm events classified by type (intensity) at Morris RDF. 37
Table 3-7. Water quality measurements for McAuliffe RDF events with Composite Sampling 41
Table 3-8. Water quality data measurements for Morris RDF events with Composite Sampling. 42
Table 3-9. Water quality parameter measurements for the Dog Park rock filter BMP. 43
Table 3-10. Load reduction estimation for events with composite sampling at McAuliffe RDF 43
Table 3-11. Load reduction estimation for events with composite sampling at Morris RDF . 44
Table 3-12. Calculated flow through rock filter Dog Park rock filter BMP for four storm events. 45
Table 3-13 Estimates of pollutant load reductions for storm events at the Dog Park rock filter BMP. 46
Table 3-14. Estimated nutrient load reduction for (2011-2012) individual events without sampling at McAuliffe RDF based on average nutrient data 46
Table 3-15. Estimated nutrient load reduction for (2011-2012) individual events without sampling at Morris RDF based on average nutrient data. 47
Table 3-16. Totalized nutrient and water quality parameter reduction for McAuliffe RDF for the period June 2011-April 2013. 48
Table 3-17. Totalized nutrient and water quality parameter reduction for Morris RDF for the period June 2011-April 2013. 49
Table 3-18. Annualized values for McAuliffe RDF nutrient and parameter reduction for the year CY (2011-2013). 50
Table 3-19. Annualized Values for Morris RDF for nutrient and parameter reduction for CY (2011-2013). 50

List of Figures

Figure 1-1. Watershed map of the McAuliffe RDF 6
Figure 1-2 Aerial view of the McAuliffe Elementary School RDF........ 7
Figure 1-3. Concept Drawing for McAuliffe Coanda screen. 9
Figure 1-4. Picture showing the coanda microscreen installation at the McAuliffe RDF Inlet. 10
Figure 1-5. Image showing the small constructed channel wetland at McAuliffe RDF........ 11
Figure 1-6 Diagram showing the plan of McAuliffe outlet RDF vegetation........ 11
Figure 1-7. Diagram Showing the cross section of McAuliffe outlet RDF vegetation. 12
Figure 1-8. Satellite image showing the Morris RDF and the two monitoring stations. 12
Figure 1-9. Constructed wetland in Morris RDF. 13
Figure 1-10. Diagram showing the plan view of Morris RDF constructed wetland........ 14
Figure 1-11. McAllen Dog Park BMP showing concrete riser and rock filter material placed around the structure to about three feet of depth. 15
Figure 2-1. McAuliffe inlet monitoring station with the inlet channel in the background. 21
Figure 2-2. ISCO 2150 AV Flow Module, 6712 automated sampler and a marine deep cycle battery powering the equipment – McAuliffe Inlet monitoring station. 23
Figure 2-3. An example of retention time estimation based on the graphical P2 method (08/31/2011, x axis: 1 stands for 5 minutes). 25
Figure 3-1. Map showing locations of RDF facilities (yellow pins) in McAllen,Texas. 29
Figure 3-2. Relationship between total inflow volume and flow reduction estimation for McAuliffe Elementary School RDF for various events. 39
Figure 3-3. Relationship between total inflow volume and flow reduction efficiencies at Morris RDF for various events. 40
Figure 3-4. Plot of flow through rock filter BMP at the Dog Park, McAllen, Texas for storm event on 8/28/11, calculated by difference between 12” inlet pipe flow and 18” outlet pipe flow. 45

1. Introduction

In the face of rapid development, urban communities are increasingly exposed to flooding during a storm. The high percentage of impervious surfaces in such communities exacerbates the existing drainage problems. Since the 1970s, regional stormwater detention basins (RDFs) have been used as one of the compensatory tools to alleviate the negative hydrological changes brought about by the advent of unrelenting urbanization. Stormwater detention basins in urban neighborhoods can serve a dual purpose. Apart from attenuating the peak discharge and flooding during a storm event, they can be a source of recreation when green spaces and other amenities are integrated into their design. Though the detention basins primarily reduce the peak runoff rate, some volume reduction can be achieved through processes such as infiltration and evaporation. Ehancements to three stormwater detention facilities in the city of McAllen have been evaluated in this project and data on runoff volume and water quality at these facilities collected since June 2011 have been used to determine the effectiveness of these RDF enhancements for removing nutrients and pollutants in the watersheds.

1.1. Project Objectives

- Collect high quality stormwater runoff nutrient and bacteria loading data for the RDF enhancements in the city of McAllen, Texas.
- Collect high quality stormwater inflow and outflow volume data at the RDFs.
- Complete engineering analysis and estimate flow and nutrient and bacteria loading reduction at the RDFs, and determine, if possible, the effect of enhancements to the RDFs.

1.2. Site description and drainage characteristics

1.2.1. McAuliffe Elementary School Regional Stormwater Detention Facility (RDF)

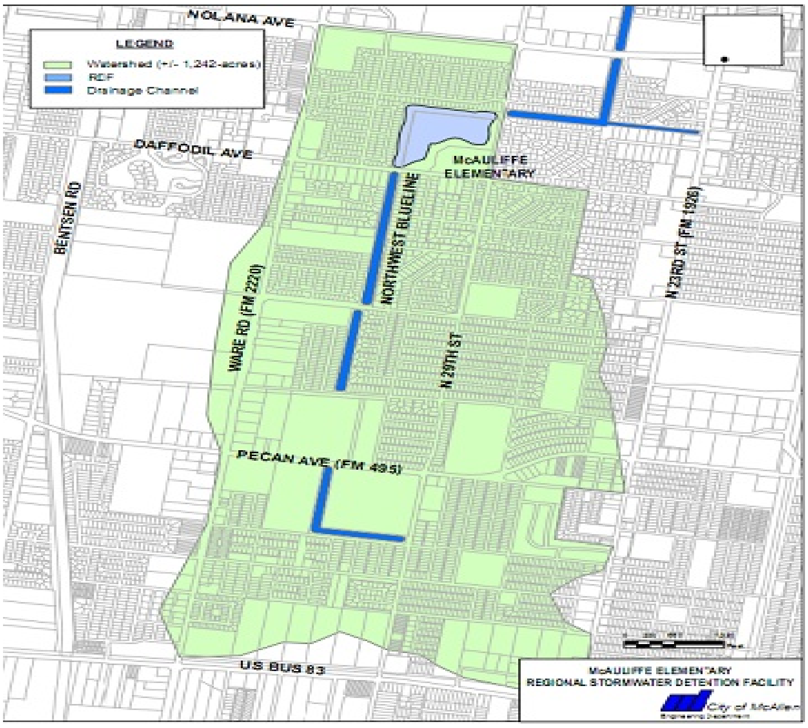


Figure 1-1. Watershed map of the McAuliffe RDF .

Source: Engineering Division, City of McAllen

Spanning a footprint of 28 acres, the McAuliffe RDF serves a drainage area of approximately 1240 acres. The McAuliffe RDF is located behind the McAuliffe Elementary School. It is a dual-purpose facility providing recreational opportunities during dry periods and stormwater detention during the wet weather. Its boundaries are Nolana Avenue on the north, US 83 Bus. on the south, Ware Road on the west and an eastern boundary extending to N 23rd Street. Figure 1-2 shows the approximate drainage area for the McAuliffe RDF. Runoff generated in the watershed is delivered to the RDF by man-made drainage channel located upstream of the RDF. The watershed is comprised mainly of urbanized landscape (80%). The flow to the RDF mainly consists of storm runoff along with some groundwater seepage. The soil in the watershed is mainly comprised of type B (92%) with type D (6%) and type C (2%) forming the rest. Approximately 15-20% of the estimated drainage area discharges to the McAuliffe RDF through an inlet at the northwestern side of the RDF (which was not monitored).

Figure 1-2. Aerial view of the McAuliffe Elementary School RDF.

Source: Google Earth

As shown in Figure 1-2, the detention basin at the McAuliffe Elementary School has gradually sloping banks. The basin also has two permanent pools on the western side. The first pool has an estimated area of 0.84 acre and the second pool has an estimated area of 1.27 acre. The pools are connected to each other by underlying concrete pipes. The water from the second pool drains out to the wetland area at the end of the basin through another concrete pipe. The permanent pools act like wet ponds and they offer more residence time for the runoff thus aiding sedimentation and infiltration. As part of this project, a small channel wetland was created near the outlet and a weir and microscreen were installed just upstream of the sampling station (the red arrow at the southwestern end of the image in Figure 1-2). The microscreen used at the McAuliffe inlet RDF site operates based on the coanda screen principle. This screen is a self-cleaning apparatus, which performs without any power requirement. The coanda screen was installed in a concrete structure built parallel to the McAuliffe inlet. The microscreen is 25 feet long and 2.5 feet wide. A head wall was built perpendicular to the channel, thereby increasing the head by 1.2 feet, Figure 1-3 below describes the coanda microscreen. The head wall is in form of removal stop logs stacked on top of each other. The screen was designed to handle flows of up to 70 cfs., whereby if the flow exceeds that amount, there will be an overflow, resulting in some debris being carried downstream. During normal operation, the incoming water flows over the screen and passes through the openings in the screen and falls into the outlet underneath which is approximately 1.5 feet deep. The debris falls into a debris-collection chamber and is cleaned out periodically.

A small wetland was constructed just before the McAuliffe RDF outlet; this wetland consists of a channel wetland of primarily bulrush plants, which can provide some treatment, and potential infiltration and reduction in the flow of stormwater from the McAuliffe basin. This wetland is located at the northeastern section of the RDF with a small drainage channel and spans a length of 185 feet and width of 15 feet. A diagram showing the location of the constructed wetland is presented as Figure 1-5. Figures 1-6 and 1-7 show the approximate dimensions and details for the outlet channel wetland at the McAuliffe RDF.

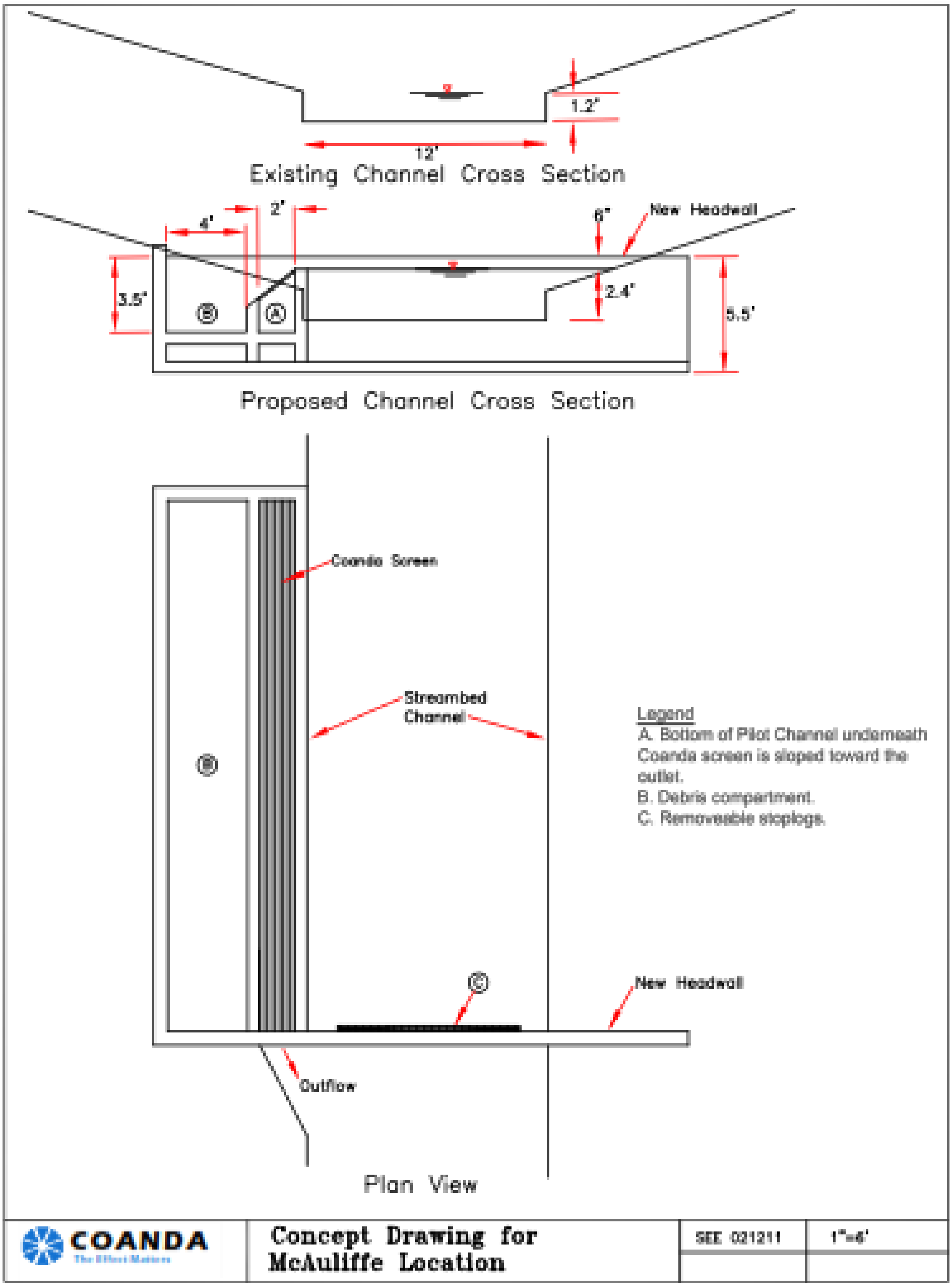


Figure 1-3. Concept Drawing for McAuliffe Coanda screen.

Figure 1-4. Picture showing the coanda microscreen installation at the McAuliffe RDF Inlet.

Figure 1-5. Image showing the constructed channel wetland at the McAuliffe RDF.

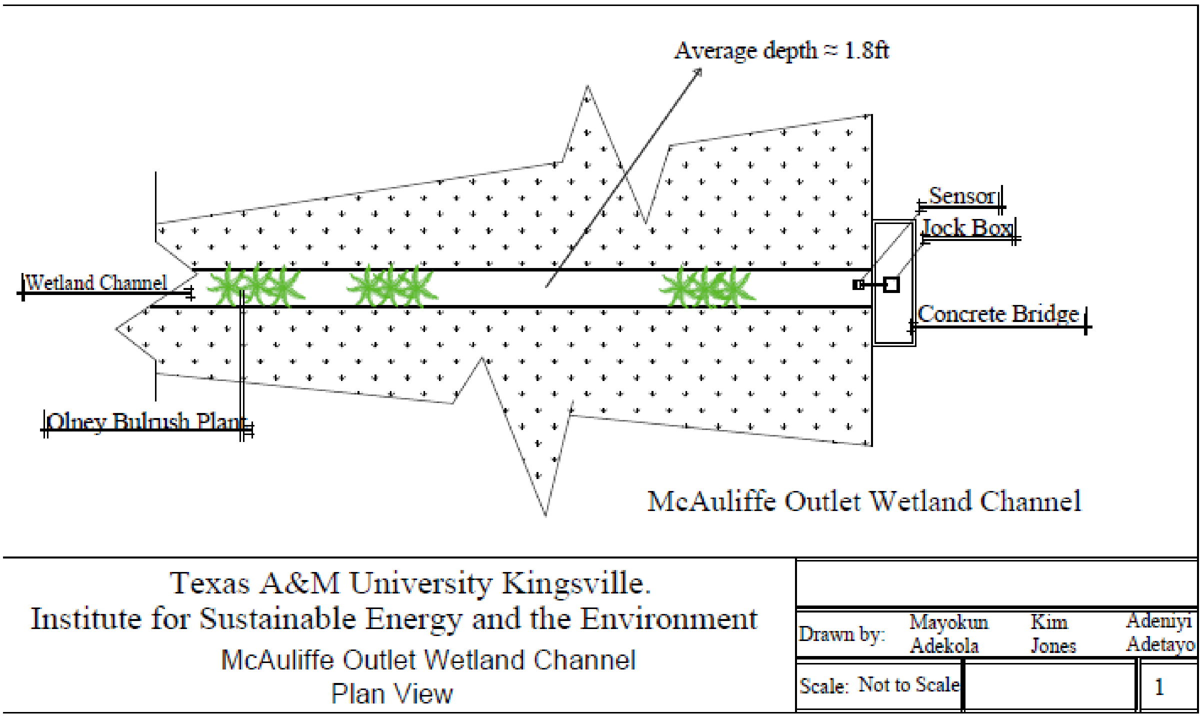


Figure 1-6. Diagram showing the plan of McAuliffe outlet RDF vegetation.

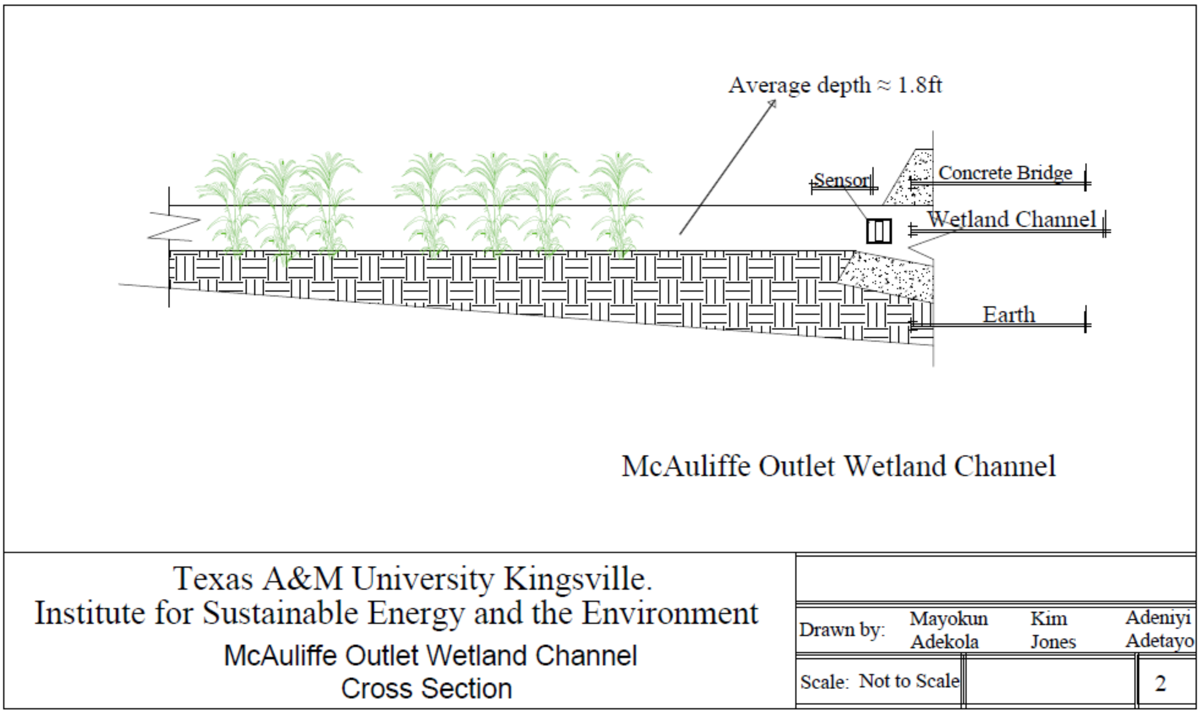


Figure 1-7. Diagram Showing the cross section of McAuliffe outlet RDF vegetation.

1.2.2. Morris Middle School RDF

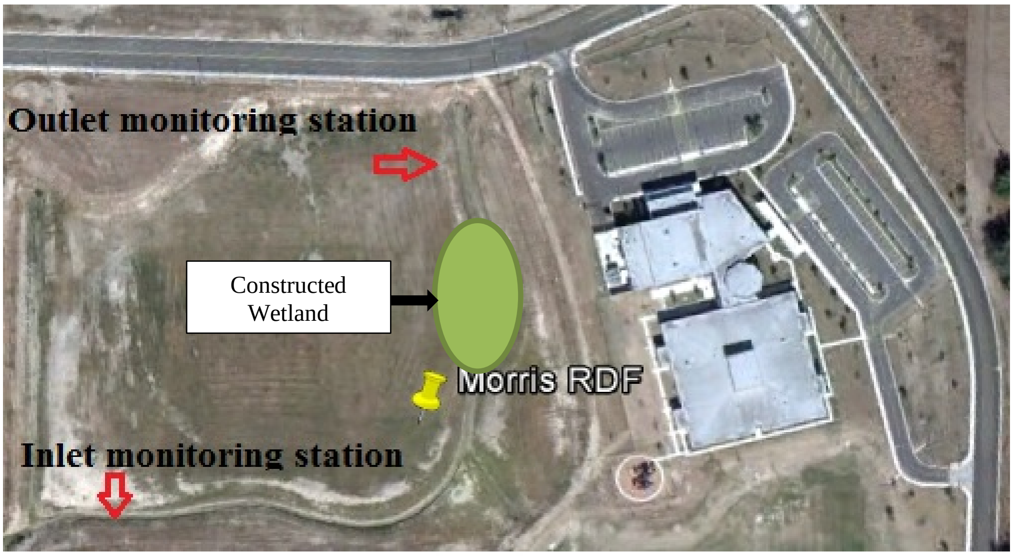


Figure 1-8. Satellite image showing the Morris RDF and the two monitoring stations.

The RDF located behind the Morris Middle School at 1400 Trenton Ave, McAllen, Texas is a facility that spans an area of 30 acres. The RDF mainly receives runoff from two drainage channels, the Bicentennial Blueline channel and the Northwest Blueline channel. Unlike the McAuliffe RDF, the Morris RDF does not have any permanent pool of water.

The Morris RDF basin is also generally deeper than the McAuliffe RDF. Since the Morris RDF was intended to serve as a recreational facility during dry weather, the basin's design includes a channel on the periphery that serves to drain some runoff from within the basin. A constructed wetland was created near the midpoint of this channel (yellow pin marker in Figure 1-8). This wetland was planted with a mixture of vegetation including California bulrush and Olney bulrush (Figure 1-9). Figure 1-10 is a plan view with dimensions of the constructed wetland at the Morris RDF.

Figure 1-9. Constructed wetland in Morris RDF.

The total drainage area of the Morris RDF is over 5,100 acres. The RDF is elliptical in shape and the slope within the RDF is ~1%. The watershed is comprised of 70 % urbanized landscape. Similar to the watershed of McAuliffe RDF, the dominant soil type in this watershed is type B soil (97%). Approximately 10-15% of the estimated drainage area discharges into the Morris RDF through an inlet at the eastern side of the Morris RDF (which was not monitored).

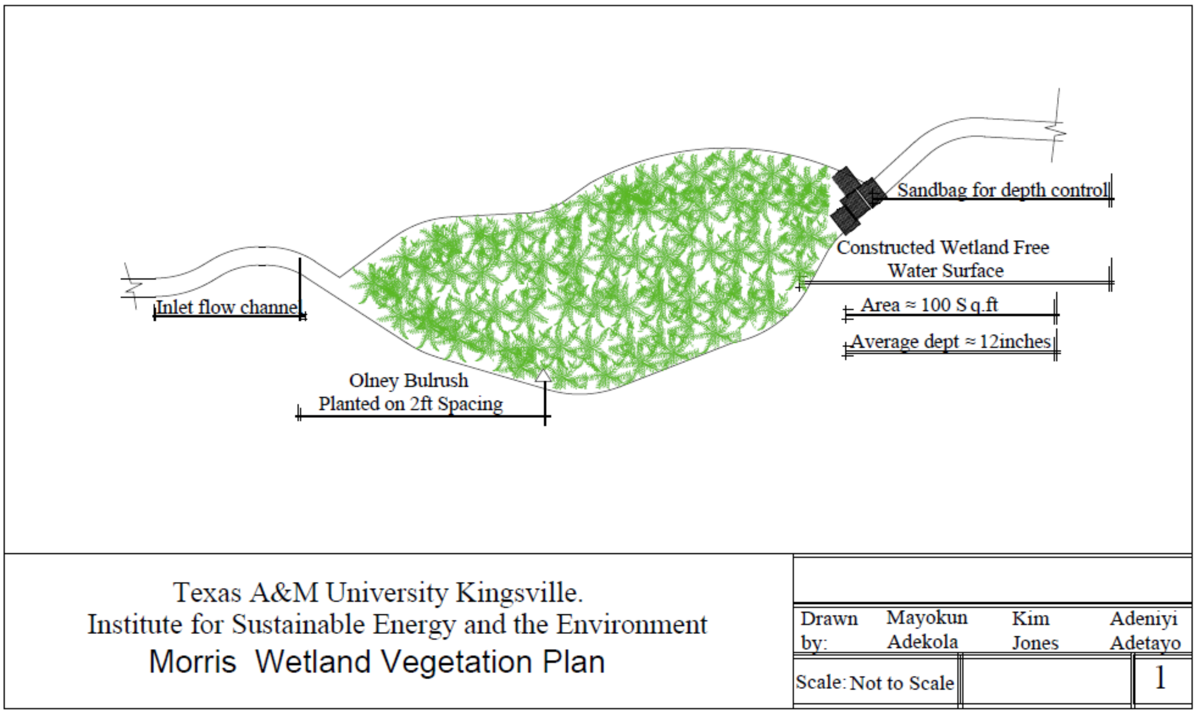


Figure 1-10. Diagram showing the plan view of Morris RDF constructed wetland.

1.2.3. McAllen Dog Park

The McAllen Dog Park located at 200 Tamarack Ave, McAllen, Texas acts as an off-line stormwater detention facility. The Dog Park spans an area of approximately 2 acres. While the McAuliffe and Morris RDFs have drainage channels with steady runoff being directed towards them, the Dog Park BMP only collected water within the one acre park. The runoff collected in the Dog Park is mainly internal runoff and some from the immediate vicinity around the Dog Park. The Dog Park has a rock filter through which the runoff passes before being delivered to the city's storm drains (Figure 1-11). When heavy flow is experienced, a riser located near the rock filter helps to bypass some of the flow and alleviate flooding.

Figure 1-11. McAllen Dog Park BMP showing concrete riser and rock filter material placed around the structure to about three feet of depth.

2. Methodology

2.1. Water Sampling and Flow Measurements

2.1.1. Sampling Process Design – McAuliffe RDF

Automated composite samplers were set up at the inlet and outlet of the McAuliffe and Morris RDFs. The sampling interval was based on flow-pacing. Compositing a sample through the entire duration of the runoff event depends on the selection of an ideal sampling interval. A flow pacing interval that is either too short or too long can cause the sampler to composite a sample that will not be truly representative of the entire duration of the runoff. Drainage basins vary in the volume of runoff generated during a storm event and this necessitates a case-by-case analysis of historical runoff volumes to arrive at a suitable flow pacing interval. The method chosen for this project is described below.

Prior to May 2012, the samplers were initially programmed to draw a fixed aliquot (100ml) for every 10,800 gallons of flow once the event started; this was based on a preliminary evaluation of historical rainfall data and drainage areas and estimated runoff coefficients. In April 2012, the flow data from days with measureable rainfall during August 2011 – March 2012 were analyzed and compared with the baseline flow date from days with no measureable rainfall. The minimum and the maximum runoff events that resulted in measureable increases in flow at the inlet and the outlet channels were identified.
The objective of this section is to describe the efforts to improve the stormwater sampling protocol adopted in the initial QAPP for flow weighted sampling of collecting a portion of the composite sample every 10,800 gallons of flow, and develop a protocol to collect a more representative composite sample for the mid-range runoff event for the RDF flow in McAllen, Texas (Texas Commission on Environmental Quality, 2012).

For the McAuliffe RDF, flow data from days with measureable rainfall over the 8 months from August 2011 through March 2012 were analyzed (approximately 14 events) and compared with the baseline flow data from days with no measureable rainfall. The minimum and the maximum runoff events that resulted in measureable increases in flow at the inlet and the outlet channels were identified and grouped.

The following criteria were used to as a basis and constraints for estimating the sampling interval for an average runoff event.

- Representative distribution of sample collection throughout the duration of the runoff event
- minimum volume required by the laboratory (lab constraint – 1.5L)
- maximum volume in the sampler vessel was 15L
- manufacturers recommendation on minimum sample aliquot volume (instrumentation sampler constraint for flow accuracy)
- sampling equipment limitations on time between sample collection cycles (instrumentation sampler purge mechanism constraint)
- ensure that while the mid-range runoff event flow distribution is fully captured, and that most higher flow events and lower flow events are accurately sampled as well

From the 2011-2012 data, a new sampling protocol was developed based on an event of 17,000 m^3 of design inlet flow to fill up a 3L volume or one 100ml aliquot for each 567 $m^3$of flow. This protocol would still allow for an accurate composite sample for an event only ½ as large – only 8,500 m^3 – to achieve a volume of the 1.5L minimum for the lab sampling. Also, since the sample bottle has a much larger capacity of 15L, this protocol could also representatively sample an event up to 5 times as large (85,000 m^3). This range of sampling would encompass over 90% of the 24 hour storm events for this area based on the historical data.
Based on these factors, the following sampling protocols were developed.

McAuliffe Inlet Sampling Considerations

Minimum Runoff Event - October 1st 2011

Table 2-1. Sampling interval for McAuliffe inlet auto sampler

Minimum Runoff Event Volume	17,000 cubic meters
Minimum Sample Volume Required by Lab Plus Safety Factor	3,000 mL
Minimum Recommended Sample Aliquot	100 mL
Number of Samples	3,000 mL/100 mL = 30 samples
Sample Interval	17,000 cubic meters/30 samples = 567 cubic meters

McAuliffe Outlet Sampling Considerations

Minimum Runoff Event - October 1st 2011

Table 2-2. Sampling interval for McAuliffe outlet autosampler

Minimum Runoff Event Volume	6,500 cubic meters
Minimum Sample Volume Required by Lab Plus Safety Factor	3,000 mL
Minimum Recommended Sample Aliquot	100 mL
Number of Aliquots per Sample	3,000 mL/100 mL = 30 Aliquots
Sampling Interval	6,500 cubic meters/30 aliquots = 216 cubic meters

2.1.2. Sampling Procedures for the Morris RDF

The project team experienced disruptions in collecting flow data at the Morris RDF. On August 19, 2011 it was discovered that the sensor setup in the Morris outlet channel was vandalized. A replacement sensor was procured in April 2012 and data collection resumed in the month of May 2012. The lack of continuous flow data did not permit the determination of sampling interval based on the flow pattern in the Morris RDF. To start with, sampling intervals determined for the McAuliffe RDF were used at Morris. Due to channelization in the Morris RDF, stormwater that enters the RDF drains out faster in comparison to the McAuliffe RDF. This resulted in the Morris RDF outlet sampling program to run its course in a far shorter duration than the Morris RDF inlet sampling program. As a corrective measure, the flow patterns were analyzed and the Morris RDF outlet sampling interval was progressively increased from 216 cubic meters (57,000 gal) to 511 cubic meters (135,000 gal) in a manner similar to that in section 2.1.1.

2.1.3. Sampling procedure for McAllen Dog Park

Sampling at the McAllen Dog Park was carried out during storm events by physical entry into the riser. Grab samples were collected from the inlet to the bio-filter and the outlet that drains out into the storm drain network. If there was no local rain in the basin, there was no flow in the riser to measure, meaning that the events at the Dog Park were expected to be less frequent than at the other RDFs.

2.2. Quality Control Techniques – for flow data

Quality Assurance for this project was provided for by continual adherence to the project QAPP, approved in 2011 and updated and renewed in 2012 and 2013 (Texas Commission on Environmental Quality, 2012).

The velocity sensors installed in each of the stormwater monitoring sites work based on the Doppler Effect. The ultrasonic waves transmitted by one transducer are picked up by another transducer after the waves are reflected off particles and air bubbles in the water stream. The quality of the velocity data produced by these sensors has a direct effect on the flow data recorded by the 2150 Flow Module. The velocity data can be affected by some anomalies such as eddy currents and other solid objects that do not represent the actual flow in the stream. Apart from an algorithm that smooths out the inconsistencies in the velocity data, three inbuilt quality control parameters exist in Flowlink to ensure that the velocity data obtained from the sensor has a high level of reliability.

2.2.1. Velocity Signal Strength

The velocity signal strength represents the percentage of signals returned back to the sensor after the signals are reflected from particles and air bubbles in the water stream. The strength of the velocity signals reflected back depends on the stream's characteristics. Some streams may exhibit low velocity signal strength values. This does not conclude that the data is erroneous. Very low particle concentration in the streams may cause this to happen. So with respect to data interpretation, a sharp drop in signal strength over a short period of time can be a cause of concern rather than a consistently low velocity signal strength reading. Also, wide and frequent fluctuation in the signal may be an indication of turbulence in the stream.

2.2.2. Velocity Spectrum Strength

As mentioned earlier, the signals received back from the particles in the stream are subject to a quality check algorithm. The percentage of signals that are verified to be genuine is represented by the spectrum strength. A higher spectrum strength value signifies a better quality signal. Low spectrum strength values can be caused by the presence of large solid objects or a low concentration of particles in the stream. Consistently decreasing spectrum strength values can be good indicators of silt deposition in the stream.

2.2.3. Spectrum Ratio

Spectrum ratio signifies the ratio of positive velocity readings to the negative velocity readings. The flow sensor can detect flow in both the forward and reverse directions. If the spectrum strength is 100% then it means that all the velocity components were in one direction. The spectrum strength values have to be inferred in conjunction with the velocity data. For example, if there was some reverse flow in a stream then the velocity sensor would record negative velocity readings. If the corresponding spectrum ratio readings were closer to 100% then it can be verified that there was indeed reverse flow. As the spectrum ratio gets closer to 0% it can be inferred that there has been an almost equal mix of positive and negative velocity readings.

2.3. Equipment and software

2.3.1. Overview of flow monitoring equipment

The following table contains information about the monitoring equipment installed at the RDFs.

Table 2-3. Equipment and software used in McAllen RDFs

Site	**Flow Monitoring**	**Sampling**	**Power Source/Data Transmission**
McAuliffe RDF	ISCO 2150 Area Velocity Flow Module	Teledyne ISCO 6712 Portable sampler	Solar Panel/ ISCO 2105 Modem
Morris RDF	ISCO 2150 Area Velocity Flow Module	Teledyne ISCO 6712 Portable sampler	Solar Panel/ ISCO 2105 Modem
McAllen Dog Park	ISCO 2150 Area Velocity Flow Module	Manual grab sampling	Solar Panel/ ISCO 2105 Modem

2.3.2. ISCO 2150 Flow Module

The ISCO 2150 Area Velocity Flow Module consists of an area velocity sensor that measures stream velocity and the stream level. These two parameters can be used, along with the cross-sectional area of the stream, to calculate the flow rate. The level of the stream is detected based on the difference in atmospheric and hydrostatic pressures acting on an internal transducer. The measurements are recorded by the sensor on a second-by-second basis. But, the data is saved once every 15 seconds to 24 hours depending on the requirement. According to the manufacturer, the memory would last for a total of 270 days if level and velocity readings are stored every 15 minutes along with total flow and input voltage every 24 hours. The flow modules at all three RDFs were programmed to store data every 5 minutes. Figure 2-1 shows the job box and sampling station at the McAuliffe inlet.

Figure 2-1. McAuliffe inlet monitoring station with the inlet channel in the background.

2.3.3. Teledyne ISCO 6712 Portable Sampler

The automated samplers used at the McAuliffe and Morris RDFs were Teledyne ISCO 6712 Portable samplers that collect composite samples based on a user-programmed frequency in a 15 liter bottle. A peristaltic pump was mounted on the controller console which was housed in a protective ABS plastic casing. The pump purged the suction line before and after collecting the sample to ensure that the suction line is not plugged. The pump can also be programmed to retry sampling up to a maximum of 3 times. The sampler's memory was capable of storing five different sampling programs. The 6712 operates on two different modes, a standard programming mode and an extended programming mode. The extended programming provides the option of collecting samples based on time, flow and rainfall events. The 6712 is connected to the 2105 via cable and the 2105 acts as the primary controller for the 6712. The 6712 can be enabled to collect samples based on various conditions like level, flow rate, rainfall, pH and temperature. All the 6712 samplers that were currently in operation in the RDFs have been programmed to enable themselves when certain level-rise conditions are satisfied.

Figure 2-2. ISCO 2150 AV Flow Module, 6712 automated sampler and a marine deep cycle battery powering the equipment – McAuliffe Inlet monitoring station.

2.3.4. Data Transmission – ISCO 2105c Modem Module

The 2105c Modem Module houses a CDMA technology based modem that can be used to transmit data from the site to the server. The 2105c also features a magnetic mount antenna that can boost the wireless reception in enclosed spaces. The receiving server's IP address and port number are fed to the 2105c to push the data. The data can be transmitted at a primary rate and a secondary rate. The secondary rate can be activated when a particular condition is met, such as a rain event. Data retrieval and other options can be accessed by connecting the 2105c to a computer running the *Flowlink* program (Texas Commission on Environmental Quality, January 2012).

2.4. Overview of Flowlink software

Flowlink is a software program developed by ISCO that is used to communicate with the ISCO 2150 Flow Module. Flowlink also performs flow calculation using the velocity and level readings from the velocity sensor. The tasks that can be performed using Flowlink are grouped into two major categories.

Site Creation and Connections to ISCO field instruments - Flowlink can be used to create a new site, list the field instruments used in the site and communicate with those instruments. Site creation can be done either through a physical connection between the field instruments and a computer running Flowlink or through a remote connection via modem. Details of the field instruments pertaining to device software version, device model number and current measurements can be viewed. It also provides the option of changing the data storage interval and data push interval (for modems).

Data retrieval and analysis – Data recorded by the ISCO field instruments can be retrieved and viewed on Flowlink. Similar to connecting to a field instrument, data retrieval can be done either through a physical connection or a remote connection. A 2105 modem can be used to transmit data using a cellular modem and it can be accessed through a server that runs the Flowlink program. The data can then be plotted on graphs and analyzed. Flowlink can also be used to save different graphical templates that can be accessed at any time. For flow measurements made using the 2150 Area Velocity module, quality control parameters such as velocity signal, signal strength and the velocity spectrum can be accessed and analyzed through Flowlink.

2.5. Volume flow reduction calculation procedure and data validation

2.5.1. Flow reduction calculation

RDF flow reduction was estimated by a graphical method (peak to peak analysis or P2 method). The results were also examined using another method which required an estimate of "mean" retention time, but this method provided results that were too sensitive to the amount of water assumed to be in the RDF prior to the event (which was largely unknown) and the estimate of storm duration, creating large variability in the outcomes. Therefore, the P2 method which appeared to generate reasonable results that could be validated through the observation of characteristic unit hydrograph curve shapes for most events, was adopted (Texas Commission on Environmental Quality, 2012).

The "Peak to peak" method was based on the estimation of the retention time between the inflow and outflow peaks. The detailed procedure is listed below:

Procedure for RDF flow reduction analysis

1) Collect and Q&A stormwater flow data for event in Flowlink software for sampling locations;

2) Estimate event duration based on the observation of the graph for the inlet in Flowlink (the storm event starts at the point when the flow rate begins to increase and ends at the point when it goes back to the base flow, e.g.: in graph 1, the duration of the storm event on 8/31/2011 was 36 hrs (2160 minutes));

3) Import flow data into Excel to draw the flow rate graph for the storm runoff events;

4) Estimate the retention time based on the time between the inlet and outlet flow rate peaks (e.g.: the time between the peaks in graph 1 is near to 4 hrs);

5) Based on the retention time estimated in step 4; calculate the event starting time in the outlet from equation 2.1:

Event starting time in outlet = event starting time in inlet + retention time…equation. 2.1

Event ending time at outlet = event ending time at inlet + retention time

6) Calculate the flow reduction during the storm events based on equation 2.2 listed below:

Event flow reduction = event inflow volume – event outflow volume ……equation .2. 2

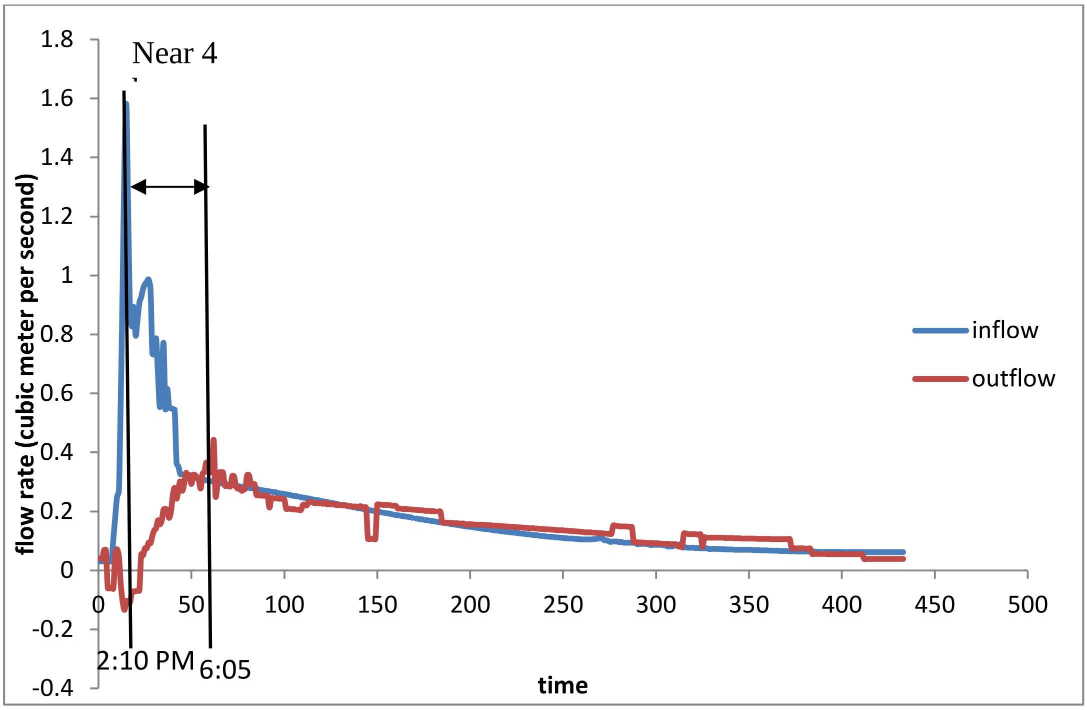


Figure 2-3. An example of retention time estimation based on the graphical P2 method (08/31/2011, x axis: 1 time unit stands for 5 minutes).

From Figure 2-3, the inflow rate and outflow rate peaks are marked in the picture to estimate the time span between them, as an estimate of retention time. On 8/31/2011, the retention time was around 4 hours based on the time span shown in the picture. Other retention time estimation examples are in Appendix B. Based on the steps 5 and 6 listed above, the flow reduction results were calculated and are shown in the Results/Discussions section.

The flow reduction is based on the various unit hydrographs, and the events in this study were divided into 3 operational categories to evaluate differences in performance based on the intensity of flow for the events
Type I included events where the inflow volumes were between 1,500 m^3 than 15,000 m^3
Type II included events where the inflow volumes were between 15,000 m^3 and 35,000 m^3
Type III included events where the inflow volumes exceeded 35,000 m^3. The total event specfics are listed in Tables 3-1 and 3-2.

2.6. Nutrient load reduction calculations

The pollutant load reduction achieved by the RDF basin was been calculated using a mass balance equation.

Load Reduction = $(Q_{in}.C_{in}) - (Q_{out}.C_{out})$

Storm events and some baseflow events were sampled and the nutrient concentration data have been used to calculate the reduction in nutrient loading on an event-by-event basis. The flow data for each event was obtained from Flowlink. The nutrient concentration data was obtained from the composite sample analysis results provided by the certified lab contractor (Analab).

The nutrient loading and reduction for each event was calculated as shown in the following example –
Site: Morris RDF
Date: 7/2/2012

Table 2-4. Data for an example calculation of nutrient reduction during a stormwater runoff event at the Morris RDF

Site	NO_2-NO_3 mg/l	TKN mg/l	TP mg/l	TSS mg/l	BOD mg/l	Volumetric flow (m^3)
Inlet	0.2	3.93	0.0433	695	28.6	13,100
Outlet	0.2	2.22	0.0141	96.0	29.0	10,200

Reduction = $(V_{in}.C_{in}) - (V_{out}.C_{out})$ [Equation 2.3]

NO_2-NO_3 reduction = $(V_{in}.C_{in}) - (V_{out}.C_{out})$ (from equation 4.1)

$$[(\mathrm{m3} * \frac{mg * 10\text{^}3}{l * 10\text{^}6}) - (m3 * \frac{mg * 10\text{^}3}{l * 10\text{^}6})]Kg$$

$$= [(13100 * \frac{0.2 * 10\text{^}3}{10\text{^}6}) - (10200 * \frac{0.2 * 10\text{^}3}{10\text{^}6})]Kg$$

= (2.62 – 2.04) = 0.58 Kg NO_2-NO_3

In Lbs = (0.58 Kg *2.204 lbs/Kg) = 1.28 lbs NO_2-NO_3

TKN reduction $= [(13100 * \frac{3.93 * 10\text{^}3}{10\text{^}6}) - (10200 * \frac{2.22 * 10\text{^}3}{10\text{^}6})]Kg$

TKN reduction = (51.48-22.64) =28.84 Kg

In Lbs =(28.84*2.204) = 63.56 lbs TKN

TN reduction = NO_2-NO_3 + TKN [Equation 2.4]

In Kg = (0.58+28.84) = 29.42 Kg

In Lbs = 1.27 + 63.56

~ 65 lbs TN

Total Phosphorus reduction $= [(13100 * \frac{0.433 * 10\text{^}3}{10\text{^}6}) - (10200 * \frac{0.141 * 10\text{^}3}{10\text{^}6})]Kg$

Total Phosphorus reduction = (5.67-1.44) Kg = 4.23 Kg

In Lbs = (4.23 Kg*2.204 lbs/Kg) = 9.33 lbs

TSS reduction $= [(13100 * \frac{695 * 10\text{^}3}{10\text{^}6}) - (10200 * \frac{96 * 10\text{^}3}{10\text{^}6})]Kg$

TSS reduction (Kg) = (9104.5-979.2)Kg = 8,125.3 Kg

TSS reduction (lbs) =(8,125.3 Kg *2.204lbs /Kg) = 17,900 lbs

$$\text{BOD reduction} = [(13100 * \frac{28.6 * 10\text{^}3}{10\text{^}6}) - (10200 * \frac{29 * 10\text{^}3}{10\text{^}6})]\ \text{Kg}$$

BOD reduction Kg = (374.66-295.80) Kg = 79 Kg

BOD reduction in Lbs =(78.86 Kg *2.204 lbs/Kg) = 174 lbs.

3. Results and discussion of flow and nutrient data collection and analysis for the RDFs and rock filter BMP

3.1. Categorization of stormwater runoff events and performance at Regional Stormwater Detention Facilities (RDFs)

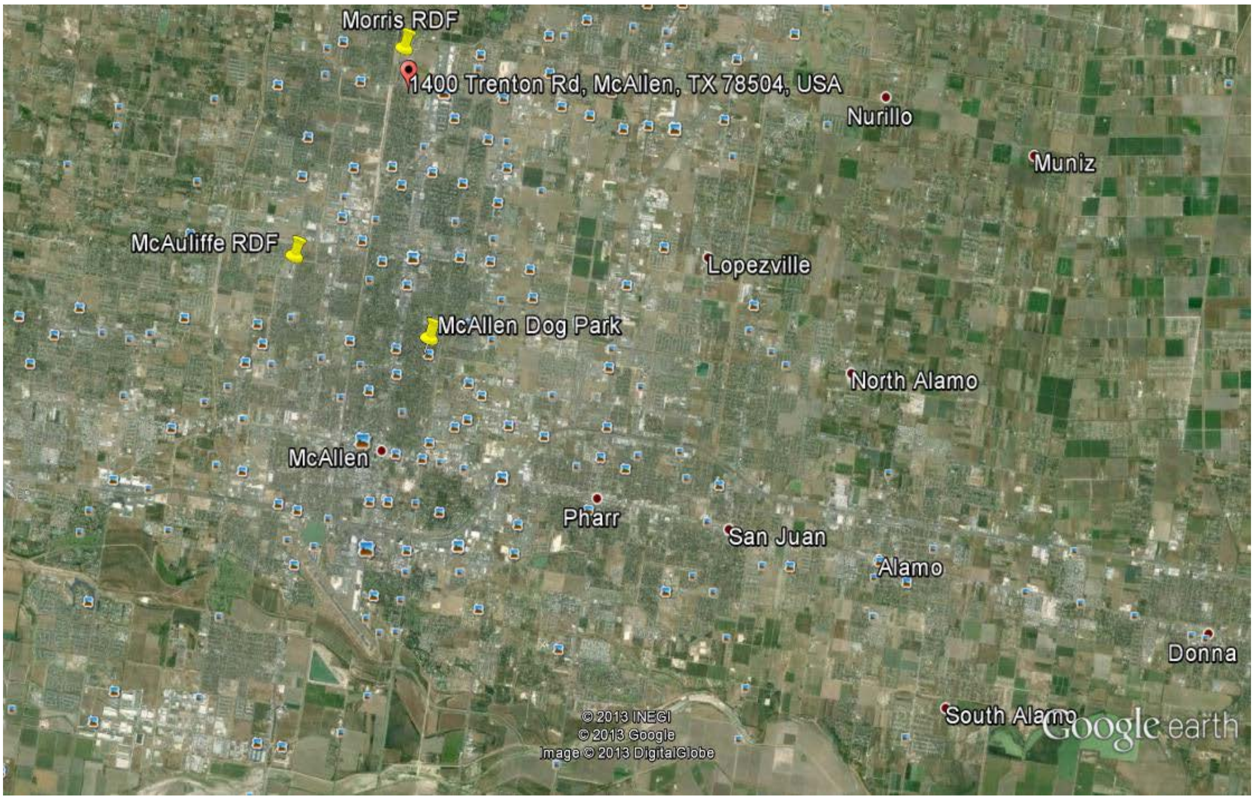


Figure 3-1. Map showing locations of RDF facilities (yellow pins) in McAllen,Texas.

The volume of runoff generated from a storm event can vary depending on the rainfall depth, landscape composition and the number of dry days before the rainfall event. Based on these factors, the runoff events have been categorized based on the volume of runoff generated within a 24-hr period starting from the time the runoff reaches the inlet channel of the respective RDF.. Historical runoff volume data for the period June 2011 – April 2012 was analyzed and utilized in the categorization of runoff events. The RDFs receive variable flow through the Blue Line drainage ditches even on days with no measureable rainfall. Instances have occurred where the local weather station (NOAA-McAllen Miller International Airport) had recorded rainfall but no corresponding changes were observed in the volume of runoff received at the RDFs. The weather station is located an estimated 4.5 miles SE of the RDF site (Figure 3-1).

It may be possible that the RDF flow and nutrient reduction results may be a function of total RDF inflow volume (a possible indicator of storm event intensity) since some biological systems have had performance affected by inlet mass loading (notably wetlands). To investigate this potential effect, the project team attempted to group events.. The following total inflow volume-based categorization based on historical data was proposed for this study:

Type I: 1,500-15,000 m^3

Type II: 15,001-35,000 m^3

Type III: >35,000 m^3

These groupings only represent an operational guideline for inflow evaluation based on observations over 24 hour periods; additional rainfall data collection throughout the watershed and more detailed characterization of the pervious surfaces would be needed to correlate these flows with regional rainfall patterns. However, these groups do represent a useful categorization for analysis as the larger flows can be assumed to be roughly correlated to significant storm events in the region.

3.2. Flow reduction analysis

Two methods (peak to peak and mean retention time) for estimating flow reduction (section 2.5) were employed to evaluate the reduction estimates for flow in both the Morris and McAuliffe RDFs. Section 3.2.1 presents the flow reduction results from "peak to peak" method and but the results were also validated by the mean retention time method in section 3.2.2. The P2 method appeared to provide more consistent results and was selected over the mean retention time method for the remainder of this study. The mean retention time method results appeared to be more sensitive to the total event duration chosen for analysis and also the estimate of the initial pool of water in the basin before the event, and both of these parameters were less than certain in many cases.

3.2.1. Flow reduction (Peak to Peak –P2 - method)

The storm runoff events were qualified (whenever the water level rose to a level of 120% of the baseline level) by the comparison between the inflow and base flow for each RDF. The events were divided into three types (based on inflow volume) and they are listed below in Table 3-1 (McAuliffe RDF) and Table 3-2 (Morris RDF):

Table 3-1. Qualified storm runoff events at McAuliffe RDF, McAllen, Texas (2011-2013).

Date and time	McAllen Airport Precipitation (in)	Total inflow volume (ft^3)	Total inflow volume (m^3)
Type I			
7/3/2011	0.8	339,000	9,600
8/25-26/2011	0.78	452,000	12,800
11/3/2011	0.07	423,776	12,000
2/5/2012	0.6	353,100	10,000
Type II			
8/31/2011	0.11	886,400	25,100
10/1/2011	0.13	579,160	16,400
2/25/2012	0.44	815,800	23,100
9/14/2012	0.71	879,300	24,900
9/27/2012	0.34	1,236,000	35,000
Type III			
6/22/2011	2.5	2,754,500	78,000
6/30/2011	1.14	1,412,580	40,000
12/10/2011	1.66	1,589,200	45,000
10/18/2012	1.37	2,683,915	76,000
2/7-8/2012	1.4	1,334,900	37,800
1/9/2013	1.6	1,589,160	45,000

Table 3-2. Qualified storm runoff events at Morris RDF, McAllen, Texas.

Date and time	McAllen Airport precipitation (in)	Total inflow volume (ft^3)	Total inflow volume (m^3)
Type I			
6/21/2012	0.43	367,300	10,400
7/18-19/2012	0.14	490,900	13,900
8/14/2012	T	353,100	10,000
8/20/2012	T	381,400	10,800
8/28/2012	T	282,500	8,000
Type II			
6/8/2012	0.06	882,880	25,000
6/30-7/1/2012	0.22	706,300	20,000
5/15/2012	0.18	1,165,400	33,000
9/1/2012	0.03	921,700	26,100
9/9/2012	0.25	635,700	18,000

9/23/2012	T	593,290	16,800
9/27/2012	0.34	600,350	17,000
Type III			
5/9/2012	0.19	4,428,500	125,400
6/23/2011	1.04	3,411,400	96,600
6/30/2011	1.14	2,927,600	82,900
7/1/2011	0.1	2,846,400	80,600
5/11/2012	1.7	4,061,200	115,000
9/14/2012	0.71	3,178,320	90,000
10/18/2012	1.37	4,661,500	132,000
1/9/2013	T	1,801,050	51,000

*T=trace rainfall (precipitation < 0.01 in)

The data from Tables 3-1 and 3-2 were plotted to look for statistical or very rough correlations between the measured rainfall at the McAllen Airport (4.5 miles from the study area) and the inlet flow volumes during the events. There was not statistically reliable correlation between the measured rainfall at the Airport and the flows. The reason for this lack of correlation is probably linked to the complexity of the pervious and non-pervious sections of the drainage areas leading to the RDFs spanning areas of 1,200 to 5,400 acres which cannot be captured using the data from a single rain guage. An evaluation of the relationships for the rainfall patterns within these watersheds and the inflow to the RDFs was outside the scope of this study. A post mortem historical analysis, using rainfall data from various City of McAllen gauges, and using runoff coefficient models may be possible in the future if such a study is deemed necessary.

Based on the procedure described in section 2.5.1, the amount of flow reduction was estimated using the P2 method for both RDF sites. In some cases, a discernable peak flow in the unit hydrograph for the inlet or outlet was not obvious. If the peak flow was not clearly detectable in either the inlet or outlet flow measurements or the difference between the inlet and outlet peaks was very small, a mean retention time based on the average of the retention times determined from earlier events was assumed in the analysis. These events are marked with an asterisk in the second column in Tables 3-3 and 3-4. The average retention time for water flows through the McAuliffe RDF using the discernable peak events was about 3 hours and 20 minutes, which was approximated as 3 hours 30 minutes (for ease of application), which was the retention time applied to those events without easily identifiable peaks for those analyses.

The most probable explanation for some events in which the estimated flow reduction resulted in a negative number is that the storm event was very localized and the rainfall resulted in flow from within the basin itself or from a smaller outfall from the residential neighborhood nearby. The last column indicates the number of flow values that had to be interpolated divided by the total number of flow data points. These interpolations across the two nearest flow data points were the most logical approach to account for some zero values from the sensors, which were probably due to interferences in the acoustic sensor measurement from sediment buildup and then wash off during the even

Table 3-3. Summary of flow reduction analysis using P2 method for the McAuliffe Elementary School RDF.

Date and time	Retention time (hrs)	Event duration (hrs)	Total inflow volume (m^3)	Total outflow volume (m^3)	Flow reduction (m^3)	Interpolated data values #interp/total#
6/22/2011	50 min	21	78,338	134,189	-55,851	3/863
6/30/2011	2hr 40min	31	39,484	22,710	16,775	2/575
7/3/2011	3 hr 30min*	29	9,600	1,866	7,734	7 /863
8/25-26/2011	3 hr 10 min	29	12,800	10,996	1,804	3/863
8/31/2011	3 hr 55 min	36	25,037	18,900	6,136	None
10/1/2011	2 hr 50 min	24	16,450	6,070	10,381	None
11/3/2011	3 hr 30min*	48	12,646	5,532	7,114	2/575
12/10/2011	2 hr 40 min	15	45,000	38,926	6,065	None
12/19/2011	3 hr 30min*	48	2,110	9,900	-7,790	None
2/5/2012	4 hr 5 min	23	10,019	11,446	-1,427	None
2/7-8/2012	3 hr 30 min*	49	37,800	10,808	27,034	None
2/25/2012	5 hr 55 min	48	23,138	8,695	14,444	None

9/14/2012	3 hr 15min	45	24,945	19,492	5,454	None
9/27/2012	3 hr 30min*	48	34,445	-7,864	42,310	None
10/18/2012	1 hr 18 min	48	76,131	26,912	49,219	None
1/9/2013	3hr 30min*	48	42,438	8,424	34,013	30/900
Average		37	30,600	20,400	14,600	Ave flow reduction/Ave inflow volume 48%
Standard Deviation		12	22,300	32,200	16,400	

*Inflow or outflow peak was not obvious for this event. Retention time was estimated as the mean value of the total event retention times.

Table 3-4. lists the flow reduction estimates for the McAuliffe RDF by storm event Type I, II or II

Table 3-4. Storm events classified by type (intensity) at McAuliffe RDF.

Date and time	Retention time (hrs)	Event duration (hrs)	Total inflow volume (m^3)	Total outflow volume (m^3)	Flow reduction (m^3)	Interpolated data values #interp/total#
Type I						
7/3/2011	3 hr 30min*	29	9,600	1,866	7,734	7/863
8/25-26/2011	3 hr 10 min	29	12,800	10,996	1,804	3/863
11/3/2011	3 hr 30min*	48	12,646	5,532	7,114	2/575
12/19/2011	3 hr 30min*	48	2,110	9,900	-7,790	None
2/5/2012	4 hr 5 min	23	10,019	11,446	-1,427	None
Average		35	9,440	7,950	1,490	Ave flow reduction/Ave inflow volume 16%
Standard Deviation		12	4,350	4,130	6,430	

Type II						
8/31/2011	3 hr 55 min	36	25,037	18,900	6,136	None
10/1/2011	2 hr 50 min	24	16,450	6,070	10,381	None
2/25/2012	5 hr 55 min	48	23,138	8,695	14,444	None
9/14/2012	3 hr 15min	45	24,945	19,492	5,454	None
9/27/2012	3 hr 30min*	48	34,445	-7,864	42,310	None
Average		40	24,800	9,060	15,750	Ave flow reduction/Ave inflow volume 64%
Standard Deviation		10	6,430	11,190	15,280	
Type III						
6/22/2011	50 min	21	78,338	134,189	--55,851	3/863
6/30/2011	2hr 40min	31	39,484	22,710	16,775	2/575
12/10/2011	2 hr 40 min	15	45,000	38,926	6,065	None
10/18/2012	1 hr 18 min	48	76,131	26,912	49219	None
2/7-8/2012	3 hr 30 min*	49	37,800	10,808	27,034	None
1/9/2013	3hr 30min*	48	42,438	8,424	34013	30/900
Average		35	53,200	40,300	12,900	Ave flow reduction/Ave inflow volume 24%
Standard Deviation		15	18,800	47,300	36,750	

*Inflow or outflow peak was not obvious for this event. Retention time was estimated as the mean value of the total event retention times.

The McAuliffe RDF with a permanent pool (two small ponds) for mixing and retention, appears to be slightly more effective for the Type II or mid size storms. From Table 3-3 the average storm water flow reduction for all of the events was 14,600 m^3 (3.86 Mgal) or 48% of inflow. From Table 3-4, the average flow reduction at McAuliffe was 1,490 m^3 (0.39 Mgals) or 16% of inflow, 15,750 m^3 (4.16 Mgals) or 64% of inflow, and 12,900 m^3 (3.41 Mgals) or 24% of inflow for Type I, II, and III events, respectively.

Tables 3-3 and 3-4 are similar results for the Morris Middle School RDF storm event outcomes. Morris RDF can be described as a small flow channel within a much larger open basin that is completely dry between storm events. Very localized events within the basin area could also cause increased outflow in outlet causing a negative flow reduction in the 6th column in Table 3-3.

Table 3-5. Summary of flow reduction using the graphical P2 method for Morris Middle School RDF.

Date	Retention Time (Hrs)	Event Duration (Hrs)	Total Inflow Volume (m^3)	Total Outflow Volume (m^3)	Flow Reduction (m^3)	Interpolation data values #interp/total#
6/23/2011	23 mins*	9.5	97,042	46,159	50,883	None
6/30/2011	23 mins*	21	82,911	127,048	-44,137	None
7/1/2011	5 min	12.4	74,731	59,165	15,566	None
5/9/2012	10 min	48	125,375	139,613	-14,255	None
5/11/2012	23 mins*	48	115,587	124,620	-9,032	None
5/15/2012	30 min	48	32,947	37,565	-4,623	None
6/8/2012	15mins	48	24,707	12,261	12,446	None
6/21/2012	10 mins	48	10,331	8,659	1,671	None
6/30-7/1/2012	35 min	48	20,008	13,287	6,721	None
7/18-19/2012	10 min	24	13,768	9,878	3,890	None
8/14/2012	55 min	24	10,041	1,288	9,113	None
8/20/2012	45 min	48	10,745	5,070	5,674	None
8/28/2012	4 hr 55 min	22	7,765	4,283	3,842	None

9/1/2012	15 min	48	26,100	20,947	5,126	None
9/9/2012	30 min	48	18,044	24,983	-6,938	None
9/14/2012	25 min	48	78,600	90,037	-11,436	None
9/23/2012	10 min	48	16,717	12,645	4,071	None
9/27/2012	5 min	48	17,120	1,885	15,234	None
10/18/2012	20 min	48	132,292	140,832	-8,545	1/1440
1/9/2013	28 min	48	51,017	49,273	1,743	71/904
04/28/2013	1 hr 50min	48	62,093	38,973	23,119	None
Average		40	48,900	46,100	2,860	Ave flow reduction/Ave inflow volume 6%
Standard Deviation		14	41,800	48,600	17,800	

*Inflow or outflow peak was not obvious for this event. Retention time was estimated as the mean value of measureable retention times.

Table 3-6. Storm events classified by type (intensity) at Morris RDF.

Date	Event Duration (Hrs)	Retention Time (Hrs)	Total Inflow Volume (m^3)	Total Outflow Volume (m^3)	Flow Reduction (m^3)	Interpolation data values #interp/total#
Type I						
6/21/2012	10 mins	48	10,331	8,659	1,671	None
7/18-19/2012	10 min	24	13,768	9,878	3,890	None
8/14/2012	55 min	24	10,041	1,288	9,113	None
8/20/2012	45 min	48	10,745	5,070	5,674	None
8/28/2012	4 hr 55 min	22	7,765	4,283	3,842	None
Average		33	10,530	5,840	4,840	Ave flow reduction/Ave inflow volume 46%

Standard Deviation		14	2,150	3,460	2,780	
Type II						
5/15/2012	30 min	48	32,947	37,565	-4,623	None
6/8/2012	15mins	48	24,707	12,261	12,446	None
6/30-7/1/2012	35 min	48	20,008	13,287	6,721	None
9/1/2012	15 min	48	26,100	20,947	5,126	None
9/9/2012	30 min	48	18,044	24,983	-6,938	None
9/23/2012	10 min	48	16,717	12,645	4,071	None
9/27/2012	5 min	48	17,120	1,885	15,234	None
Average		48	22,200	17,700	4,580	Ave flow reduction/Ave inflow volume 21%
Standard Deviation		0	5,540	10,600	7,540	
Type III						
6/23/2011	23 mins*	10	97,042	46,159	50,883	None
6/30/2011	23 mins*	21	82,911	127,048	-44,137	None
7/1/2011	5 min	12	74,731	59,165	15,566	None
5/9/2012	10 min	48	125,375	139,613	-14,255	None
5/11/2012	23 mins*	48	115,587	124,620	-9,032	None
9/14/2012	25 min	48	78,600	90,037	-11,436	None
10/18/2012	20 min	48	132,292	140,832	-8,545	1/1440
1/9/2013	28 min	48	51,017	49,273	1,743	71/904
4/28/2013	1 hr 50min	48	62,093	38,973	23,119	None
Average		37	91,070	90,600	434	Ave flow reduction/Ave inflow volume 1%
Standard Deviation		17	28,400	42,900	26,900	

*Inflow or outflow peak was not obvious for this event. Retention time was estimated as the mean value of measureable retention times.

The Morris Middle School RDF without a permanent pool or pond but with a small wetland for mixing and retention, appears to be slightly more effective for the Type I or smaller size storms. From Table 3-5 the average storm water flow reduction for all of the events was 2,860 m^3 (0.76 Mgal) or 6% of inflow. From Table 3-6, the average flow reduction at Morris was 4,840 m^3 (1.27 Mgals) or 46% of inflow, 4,580 m^3 (1.19 Mgals) or 21% of inflow, and only 434 m^3 (0.12 Mgals) or 1% of inflow for Type I, II, and III events, respectively.

3.2.2. Correlation analysis between total inflow volume and flow reduction

An evaluation was made to determine if any apparent correlations existed between event inflow volume and total flow volume reduction estimated for that event at each of the RDFs. Some relationship testing for these parameters is shown in the following figures:

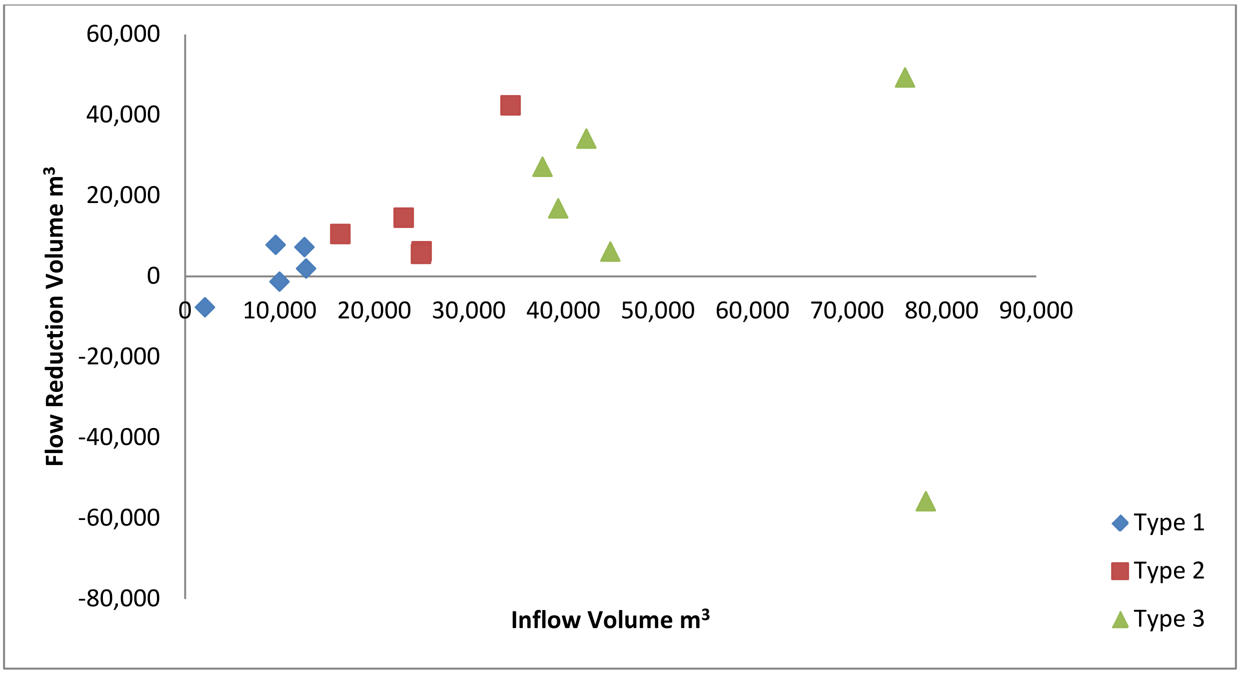


Figure 3-2. Relationship between total inflow volume and flow reduction estimation for McAuliffe Elementary School RDF for various events.

From Figure 3-2 is appears that with one exceptional outlier the amount of flow reduction is roughly correlated to the size of the event at the McAuliffe RDF. This the RDF with storage ponds and a permanent pool of water storage.

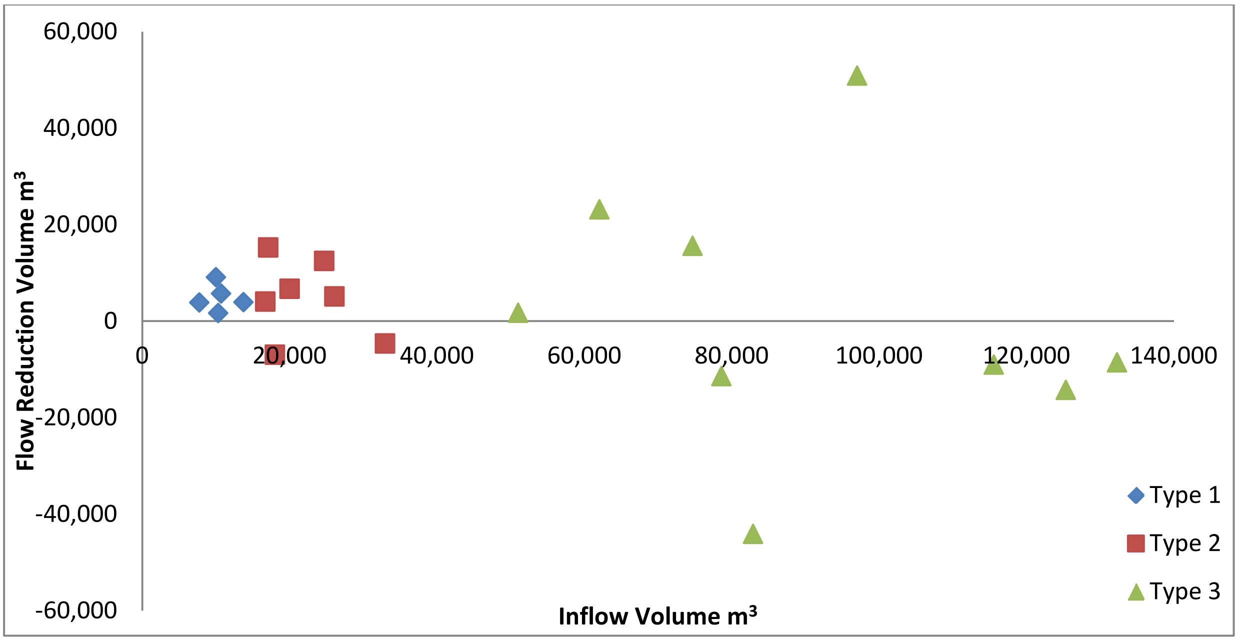


Figure 3-3. Relationship between total inflow volume and flow reduction efficiencies at Morris RDF for various events.

From Figure 3-3 the relationship between flow reduction and storm event size is less clear for the Morris Middle School RDF. This is the basin without a permanent pool of storage but with a much larger catchment area. Some of the variability in the outcomes could be due to intense localized rainfall and runoff within the basin itself evidenced by the negative reductions from the inlet to the outlet, especially for the larger size events.

3.3. RDF Nutrient load reduction analysis

3.3.1. Nutrient load reduction analysis for events with composite sampling.

Water quality and nutrient load analysis based on lab data results from composite sampling at the two RDF sites are listed below in Tables 3-7 and 3-8.

Table 3-7. Water quality measurements for McAuliffe RDF events with Composite Sampling.

Date of Event	McAuliffe RDF	Total volume (m^3)	NO_2-NO_3 (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	TSS (mg/l)	*E.coli* MPN/100ml	BOD (mg/l)
6/28/2011	Inflow	baseline	1.40	0.89	2.29	0.27	20	1,203	5
	Outflow	baseline	1	0.99	1.99	0.25	17	770	6
8/19/2011	Inflow	5,948	2.55	0.96	3.51	0.10	94	201	12
	Outflow	*-1,814	1	1.76	2.76	0.24	38	73	26
12/10/2011	Inflow	72,537	1	1.35	1.94	0.46	204	Ex HT	22
	Outflow	71,832	1	1.23	1.98	0.21	34	Ex HT	8
12/19/2011	Inflow	2,110	1.98	1.18	3.16	0.09	77	236	4
	Outflow	9,900	1	1.2	1.6	0.13	43	687	7
2/8/2012	Inflow	37,800	1	0.46	0.85	0.31	46	>2,419	5
	Outflow	10,808	1	0.78	1.20	0.24	60	>2,419	6
5/4/2012	Inflow	3,311	1	2.4	2.6	0.25	92	2,180	78
	Outflow	5,215	1	8.09	8.29	1.47	120	86,640	135
June - December (2012) construction of microscreen event									
1/9/2013	Inflow	42,438	1	3.42	4.42	0.86	836	Ex HT	21
	Outflow	8,424	1	2.12	3.12	0.17	13	Ex HT	10
4/30/2013	Inflow	46,568	1	3.11	3.36	1.07	587	Ex HT	17
	Outflow	5,162	1	1.25	1.45	0.65	43	Ex HT	9
Total		320,239	17	29	40	6.00	2,287	94,855	360
Average value		22,874	1.18	2.09	2.87	0.45	163	11,857	26
Standard Deviation		26,148	0.47	1.93	1.86	0.42	242	30,234	37

*Reverse flow of stormwater at the outlet into the wetland

Ex HT - exceeded holding time

06/28/2011 – The first sample collected was a baseline grab sample, no flow recorded.

4/30/2013 – Grab sample was collected at McAuliffe outlet only.

Table 3-8. Water quality data measurements for Morris RDF events with Composite Sampling.

Date	Morris RDF	Total volume (m^3)	NO_2-NO_3 (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	TSS (mg/l)	*E.coli* MPN/100ml	BOD (mg/l)
6/28/2011	Inflow	baseline	<1	0.9	1.9	0.2	25	1,413	6
	Outflow	baseline	<1	0.5	1.5	0.3	55	1,732	7
8/19/2011	Inflow	**	<1	0.5	1.5	0.3	44	361	24
	Outflow	**	<1	0.6	1.6	0.3	250	1414	9
12/19/2011	Inflow	**	<1	1.0	2.0	0.4	647	387	5
	Outflow	**	<1	0.5	1.5	0.1	46	365	7
5/4/2012	Inflow	132,292	1	1.2	2.2	0.1	140	1,220	13
	Outflow	140,832	1	2.5	3.5	0.1	63	1,220	6
6/22/2012	Inflow	51,017	1	2.5	3.5	0.3	78	Ex HT	Ex HT
	Outflow	49,273	1	1.7	2.7	0.6	47	Ex HT	Ex HT
7/1/2012	Inflow	20,008	1	3.9	4.9	0.4	695	10,000	29
	Outflow	13,287	1	2.2	3.2	0.1	96	20,000	29
7/19/2012	Inflow	13,768	1	3.1	4.1	0.3	313	43,520	57
	Outflow	9,878	1	2.1	3.1	0.2	89	31,000	29
9/1/2012	Inflow	26,100	1	0.8	1.8	0.1	160	Ex HT	Ex HT
	Outflow	20,947	1	1.1	2.1	0.1	15	Ex HT	Ex HT
9/9/2012	Inflow	18,044	1	2.0	3.0	0.3	96	>2420	17
	Outflow	24,983	1	1.4	2.4	0.2	25	>2420	16
10/18/2012	Inflow	132,292	1	4.2	5.2	1.4	2,270	61,310	9
	Outflow	140,832	1	5.2	6.2	1.1	853	57,940	12
1/9/2013	Inflow	51,017	1	0.9	1.9	0.1	81	Ex HT	11
	Outflow	49,273	1	1.0	2.0	0.1	138	Ex HT	15
4/30/2013	Inflow	62,093	1	2.5	3.5	0.6	317	Ex HT	12
	Outflow	38,974	1	2.1	3.1	0.9	256	Ex HT	13
Total		994,910	18	40.5	58.5	7	5,732	211,050	249
Average value		55,273	1	2.2	3.2	0.4	318	23,405	20
Standard Deviation		47,308	0	1.0	1.0	0	538	25,338	14

Ex HT - exceeded holding time

06/28/2011 - The first stormwater grab sample was baseline value, no flow data recorded.

** On August 19, 2011 it was discovered that the sensor setup in the Morris outlet channel was vandalized. A replacement sensor was not available until April 2012 and data collection resumed in the month of May 2012. Quarterly sampling of baseline water quality was conducted.

Table 3-9. Water quality parameter measurements for the Dog Park rock filter BMP.

Date		NO_2-NO_3 (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	TSS (mg/l)	BOD (mg/l)	*E.coli* MPN/100ml
2/8/12	in	<1	1.21	1.21	0.458	7	6.19	Ex HT
	out	<1	0.964	1.22	0.169	8	2.47	Ex HT
Est. rem.		0	0.246	-0.01	0.289	-1	3.72	NA

Table 3-10. Load reduction estimation for events with composite sampling at McAuliffe RDF.

Event date	Flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN)
6/28/2011	Baseline	4.3	2.6	6.9	0.8	58	15	2E+06
8/19/2011	7,762	37.4	19.6	57.0	0.9	1,384	263	1E+10
12/10/2011	705	-24.1	21.1	-3.0	40.9	27,263	2,230	NA
12/19/2011	-7,790	0.5	-20.7	-20.2	-2.5	-580	2,230	5E+09
2/8/2012	26,992	22.2	19.6	41.8	19.8	2,403	-134	7E+11
5/4/2012	-1,904	-0.8	-75.5	-76.3	-15.0	-708	299	-4E+12
1/9/2013	34,014	75.0	280.5	355.5	77.4	77,953	1,771	NA
4/30/2013	41,406	25.7	319.2	344.9	109.8	60,235	1,714	NA
Total Values	101,185	135.8	563.9	699.7	231.4	167,950	8,373	-3E+12
Ave. values	14,455	19.4	80.6	100.0	33.1	23,993	1,196	**-8E+11**

Table 3-10 is an estimate of the mass of nutrient or constituent reduction for the McAuliffe RDF calculated using Equation 2.3 as presented in Section 2.6 above.

From Table 3-10, it appears that some significant nutrient and bacteria load reductions were achieved in the McAuliffe RDF for various size storm events. An average load reduction of 19 lbs of NO_2-NO_3, 81 lbs of TKN, 100 lbs of TN, 33 lbs of TP, and 1,196 lbs of BOD appeared to be reduced for each event in which samples were collected. An average value of 24,000 lbs of sediment removed per event is also significant, along with some bacterial reduction but reliable bacterial data were difficult to achieve within the holding times required.

Table 3-11. Load reduction estimation for events with composite sampling at Morris RDF.

Event date	Flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN /100ml)
5/4/2012	-8,540	-18.8	-405.1	-423.9	-4.8	21,265	1,787	-1E+11
6/21/2012	1,744	3.8	97.5	101.4	-40.9	3,666	NA	NA
7/1/2012	6,721	14.8	108.3	123.1	15.0	27,837	411	-7E+11
7/19/2012	3,890	8.6	47.1	55.7	4.9	7,565	1,082	3E+12
9/1/2012	5,153	11.4	-4.0	7.3	2.3	8,498	NA	NA
9/9/2012	-6,939	-15.3	4.0	-11.3	-0.2	2,458	-204	-2E+07
10/18/2012	-8,540	-18.8	-410.4	-429.2	67.0	397,102	-1,172	-5E+07
1/9/2013	1,744	3.8	-10.1	-6.3	2.4	-5,879	NA	NA
4/30/2013	23,119	51.0	166.4	217.3	0.9	21,392	105	NA
Total Values	18,352	40.4	-406.3	-365.9	46.4	483,903	2,009	2E+12
Ave. values	2,039	**4.5**	**-45.1**	**-40.7**	**5.2**	**53,767**	**287**	**4E+11**

Table 3-11 is an estimate of the mass of nutrient or constituent reduction for the Morris RDF calculated using Equation 2.3 as presented in Section 2.6 above.

From Table 3-11, it appears that some less significant nutrient and bacteria load reductions were achieved at the Morris Middle School RDF for various size storm events. It is possible that rainfall entering the RDF through unmonitored inlets and rainfall in the basin itself contributed significantly to the flow at the outlet in some cases. An average load reduction of only 4.5 lbs of NO_2-NO_3,and no significant TKN or TN reduction per event were measured, while 287 lbs of BOD and 5.2 lbs TP removals per event were measured. An average removal of sediment of 53,767 lbs per event appears significant, along with some bacterial reduction but this is skewed by one very large removal event on 10/18/12.

The next few tables and figures document the performance and estimates of nutrient and pollutant load reductions for the small rock filter at the Dog Park in McAllen.

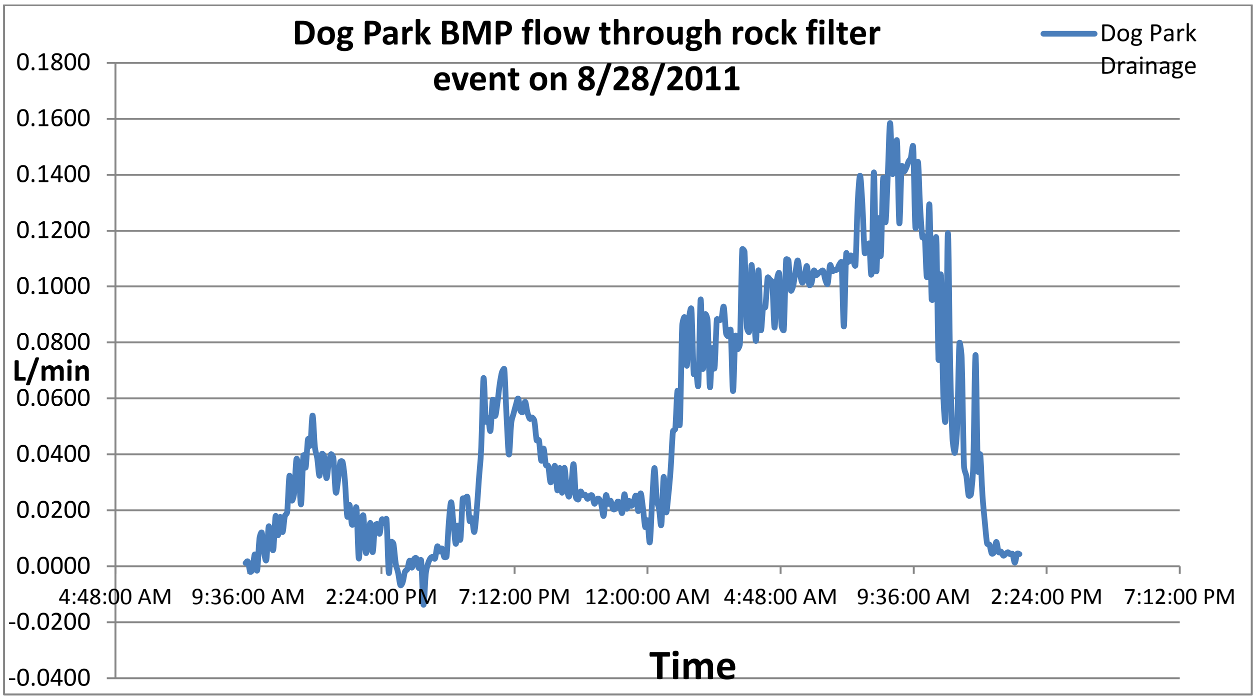


Figure 3-4. Plot of flow through rock filter BMP at the Dog Park, McAllen, Texas for storm event on 8/28/11, calculated by difference between 12" inlet pipe flow and 18" outlet pipe flow.

Table 3-12. Calculated flow through rock filter Dog Park rock filter BMP for four storm events.

Event Date	Event duration (hrs)	Inlet pipe inflow volume (m^3)	Outlet pipe outflow volume (m^3)	Flow through rock Filter (m^3)	Interpolated data values #interp/total#
8/28/2011	28	7	13	6	5/454
8/31/2011	3	86	120	34	None
6/21/2012	2.5	13	61	48	None
6/23/2012	1	1.5	5.5	4	None

Table 3-13 Estimates of pollutant load reductions for storm events at the Dog Park rock filter BMP.

Event Date	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN)
8/28/2011	0	0.003	0.000	0.004	-0.013	0.049	NA
8/31/2011	0	0.018	-0.001	0.022	-0.075	0.278	NA
6/21/2012	0	0.026	-0.001	0.031	-0.106	0.393	NA
6/23/2012	0	0.002	0.000	0.003	-0.009	0.033	NA
Totals	0	0.050	-0.002	0.058	-0.202	0.753	NA

From Tables 3-12 and 3-13, while the Dog Park rock filter BMP is a small volume control measure, the principle of such an application could be applied in other areas of the watershed requiring additional treatment for pollutant runoff. Some TKN, Phosphorous and BOD were apparently removed in this BMP. More sampling and data collection are needed to confirm these results.

3.3.2. Nutrient and bacteria load reduction estimation in storm events without composite sampling

Table 3-14. Estimated nutrient load reduction for (2011-2012) individual events without sampling at McAuliffe RDF based on average nutrient data.

Event date	flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN(lbs)	TP(lbs)	TSS(lbs)	BOD(lbs)	*E.coli(MPN)*
Type I								
7/3/2011	7,734	20.1	35.7	49.0	7.6	2,784	439	8E+06
8/25-26/2011	1,804	4.7	8.3	11.4	1.8	649	102	2E+07
11/3/2011	7,114	18.5	32.8	45.1	7.0	2,561	404	7E+07
2/5/2012	-1,427	-3.7	-6.6	-9.0	-1.4	-514	-81	-1E+07
Type II								
8/31/2011	6,136	16.0	28.3	38.9	6.0	2,209	348	6E+07
10/1/2011	10,381	27.0	47.9	65.8	10.2	3,737	590	1E+08
2/25/2012	14,444	37.6	66.6	91.5	14.2	5,200	820	1E+08
9/14/2012	5,454	14.2	25.2	34.6	5.4	1,963	310	5E+07
9/27/2012	42,310	110.1	195.2	268.0	41.6	15,232	2,403	4E+08
Type III								
6/22/2011	-55,851	-145.3	-257.6	-354	-54.9	-20,107	-3,172	-6E+08

6/30/2011	16,775	43.7	77.4	106	16.5	6,039	953	2E+08
12/10/2011	6,065	15.8	28.0	38	6.0	2,183	344	6E+07
10/18/2012	49,219	128.1	227.1	312	48.4	17,719	2,795	5E+08
2/7-8/2012	27,034	70.4	124.7	171	26.6	9,732	1,535	3E+08
Total for all	**137,192**	**357**	**633**	**869**	**135**	**49,390**	**7,792**	**1E+09**

For those events where nutrient and bacteria analyses were not available, the nutrient and bacteria load reduction was estimated by the product of event total volume flow reduction and average nutrient load per unit volume estimated from all of the prior monitored events. Table 3-14 is the estimation of total nutrient load reduction in the McAuliffe RDFs for the events listed in Table 3-4 multiplied by the average loading data (inlet and outlet) in Table 3-7. Table 3-15 is the estimation of nutrient load reduction at Morris RDF for the events listed in Table 3-6 and using the average loading data (inlet and outlet) in Table 3.8.

Table 3-15. Estimated nutrient load reduction for (2011-2012) individual events without sampling at Morris RDF based on average nutrient data.

Event date	flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN)
Type I								
6/8/2012	12,446	27.4	61.7	89.1	11.1	8,735	549	3E+12
8/14/2012	9,113	20.1	45.2	65.3	8.1	6,396	402	2E+12
8/28/2012	3,842	8.5	19.0	27.5	3.4	2,696	169	9E+11
9/1/2012	5,126	11.3	25.4	36.7	4.6	3,598	226	1E+12
9/23/2012	4,071	9.0	20.2	29.2	3.6	2,857	179	1E+12
Type II								
5/9/2012	-14,255	-31.4	-70.7	-102.1	-12.7	-10,005	-628	-3E+12
5/15/2012	-4,623	-10.2	-22.9	-33.1	-4.1	-3,245	-204	-1E+12
8/20/2012	5,674	12.5	28.1	40.6	5.0	3,982	250	1E+12
9/27/2012	15,234	33.6	75.5	109.1	13.5	10,692	672	4E+12
Type III								
6/23/2011	50,883	112.1	252.2	364.4	45.2	35,711	2,243	1E+13
6/30/2011	-44,137	-97.3	-218.8	-316.0	-39.2	-30,977	-1,946	-1E+13
7/1/2011	15,566	34.3	77.2	111.5	13.8	10,925	686	4E+12
5/11/2012	-9,032	-19.9	-44.8	-64.7	-8.0	-6,339	-398	-2E+12
9/14/2012	-11,436	-25.2	-56.7	-81.9	-10.2	-8,026	-504	-3E+12
Total for all	**38,472**	**85**	**191**	**275**	**34**	**27,001**	**1,696**	**9E+12**

3.4. Load reduction estimation for all of the 2011-2012 events

A unique aspect of this evaluation was the utilization of the continuous monitoring of flow into and out of the two RDF structures for comparison, and the estimation of load reductions using the data above presented inTables 3.10, 3.11, 3.14 and 3.15. It is clear that large detention and retention system basins in parts of the Rio Grande and Arroyo Colorado watershed, when fitted with enhanced treatment features, can be significant contributors to pollutant reduction. The basin design at McAuliffe with a set of permanent ponds for retention appears to be more efficient than the emphemeral (commonly dry basin) at the Morris Middle School for removing most pollutants. The stormwater wetland at Morris probably helps remove nutrients but it can be easily bypassed during large events.

Overall this project has demonstrated that during the relatively dry years spanning 2011, 2012 and 2013, it can be estimated that the two RDF structures have removed a total of 618 lbs. of NO_2-NO_3, 981 lbs. of TKN, 1,474 lbs. of TN, 447 lbs. of TP, 330 tons of TSS, and 19,437 lbs. of BOD. Bacteria reduction estimates for these BMPs were complex. While 2×10^{12} *E.coli* (MPN) bacteria were apparently removed from the watershed at the Morris RDF, some events at McAuliffe appeared to increase the bacteria population in the outflow.
This was possibly due to some high volume events in which reverse flows occurred at the inlet and outlet Reverse flows may have resulted from large runoff volumes directly entering the downstream RDF from sources other than the McAuliffe outlet, causing its level to rise faster than the level in the McAuliffe RDF.. Thus these estimates for removal have some uncertainity but are conservative, because neither inflow from the northeastern drainage pipe nor back-flow from the downstream RDF was accounted for in the calculation of flow and pollutant inputs to the RDF.

Table 3-16. Totalized nutrient and water quality parameter reduction for McAuliffe RDF for the period June 2011-April 2013.

Event date	Flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN)
McAuliffe RDF Sampling	101,185	136	564	700	231	167,600	8,373	-3.E+12

McAuliffe RDF Estimated	137,192	357	633	869	135	49390	7,792	1.E+09
Total Estimate	238,377	493	1,197	1,569	366	216,990	16,165	-3.E+12

The totalized estimate for nutrient and water quality parameter reduction in Table 3-16 was determined by summing the results from the McAuliffe RDF sample collection events and the results from those events with estimated values using the average constituent concentrations. The totalized value for McAuliffe RDF shows a significant flow reduction and removal of a considerable amount of nutrients over the span of two years.

Table 3-17. Totalized nutrient and water quality parameter reduction for Morris RDF for the period June 2011-April 2013.

RDF	Flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN(lbs)	TP(lbs)	TSS(lbs)	BOD(lbs)	*E.coli(MPN)*
Morris RDF events Samples collected	18,352	40.4	-406.3	-365.9	46.4	483,903	2,009	2E+12
Morris RDF events Estimated	38,472	84.8	190.7	275.5	34.2	27,001	1,263	1E+06
Totalized Value	56,824	125.2	-215.6	-90.4	80.6	510,904	3,272	2E+12

The totalized estimate for nutrient and water quality parameter reduction in Table 3-17 was determined by summing the results from the Morris RDF sample collection events and the results from those events with estimated values using the average constituent concentrations. The totalized value for Morris RDF shows a significant reduction in flowrate and the removal of some key nutrients, especially TSS.

Table 3-18 shows an estimate for annualized nutrient reductions for the McAuliffe RDF which were determined by summing the total sampling and estimated value for each year from Table 3-10 and 3-14, then multiplying the total value by the number of months in a year and dividing by the number of months the events occurred.

$$\text{Annualized value for 2011} = \frac{(total\ value \times 12\ months)}{(months\ of\ events)} = \frac{(835m^3 \times 12)}{(7)} = 1{,}431\ \text{m}^3$$

Table 3-18. Annualized values for McAuliffe RDF nutrient and parameter reduction for the year CY (2011-2013).

Year		Flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN)
2011	Total	835	15	-37	34	40	28,122	4,731	2E+10
	Annualzied Value	**1,431**	**26**	**-63**	**58**	**69**	**48,209**	**8,110**	**3E+10**
2012	Total	162,392	378	576	833	140	51,027	8,662	-3E+12
	Annualzied Value	**216,523**	**504**	**768**	**1,111**	**187**	**68,036**	**11,549**	**-4E+12**
2013	Total	75,420	101	600	700	187	138,188	3,485	ExHT
	Annualzied Value	**226,260**	**302**	**1,799**	**2,101**	**561**	**414,563**	**10,455**	**ExHT**

Table 3-19 shows an estimate for annualized nutrient reductions for the Morris RDF which were determined by summing the total sampling and estimated value for each year from Table 3-11 and 3-15, then multiplying the total value by the number of months in a year and dividing by the number of months the events occurred.

$$\text{Annualized value for 2011} = \frac{(total\ value \times 12\ months)}{(\ months\ of\ events)} = \frac{(22{,}262m^3 \times 12)}{(2)} = 133{,}572\ \text{m}^3$$

Table 3-19. Annualized Values for Morris RDF for pollutant reductions for CY (2011-2013).

Year		Flow reduction (m^3)	NO_2-NO_3 (lbs)	TKN (lbs)	TN (lbs)	TP (lbs)	TSS (lbs)	BOD (lbs)	*E.coli* (MPN)
2011	Total	22,262	49	111	160	20	15,659	983	5E+12
	Annualzied Value	**133,572**	**294**	**666**	**960**	**120**	**93,954**	**5,898**	**3E+13**
2012	Total	9,649	21.4	-483	-461	58	479,732	2,617	6E+12
	Annualzied Value	**19,298**	**42.8**	**-965**	**-922**	**115**	**959,464**	**5,234**	**1E+13**
2013	Total	24,863	55	156	211	3	15,513	105	ExHT

	Annualzied Value	**74,589**	**165**	**468**	**633**	**9**	**46,539**	**315**	**ExHT**

References

Texas Commission on Environmental Quality (January 2012). *Surface Water Quality Monitoring Data Management Reference Guide.* Austin: TCEQ.

Quality Assurance Project Plan. (April 2012). *QAPP for Development and Implementation of Innovative Storm Water Regional Detention Facilites for Urban Water Quality Improvement in the Arroyo Colorado,* developed for TCEQ by A&M Kingsville project team, Kingsville, Texas.

Pan, X., Zhang, J., Fang, W., Jones, K. (2012) Dynamic behavior of stormwater quality parameters in South Texas, *Frontiers of Environmental Science and Engineering*, v6:6, 825-830.

Pan X. , K. Jones, J. Guerrero, A. Garza, S. Wang. (2010) Innovative Best Management Practices (BMPs) design and data analysis for urban stormwater quality improvement in South Texas, USA. *17th World Congress of CIGR*, Quebec City, Canada, June 13-17.

Balakrishnan, V. (2012) *Evaluation of nutrient removal from urban stormwater runoff using a coanda-effect screen*, M. S. Thesis, Texas A&M University-Kingsville.

Jones, K., Oluwatosin ,O., Adetayo, A., Balakrishnan, V. and Zhang, J. (2013) "Assessment of BMPs-RDF for Stormwater-Runoff Management at Lower Rio Grande Valley for Urban Water Quality in the Arroyo Colorado," poster presented at the *15th Annual Water Quality Management and Planning Conference*, South Padre Island, Texas, April 16-19.

Appendix A

Discussion of some challenges in implementing the sampling program and the volume reduction calculations

At the **McAuliffe RDF**, in May 2012, ISCO's technical support team informed the project team that the "level rate of change" program used for enabling the samplers had some deficiencies and also suggested that the samplers should be set to enable on a "level threshold". Subsequently, the samplers at both Morris and McAuliffe RDFs were set to enable themselves based on a predetermined increase in the water level in the channel. Morris inlet and outlet samplers were set to enable when the water level in the channel rose to 1.4 ft and 1.2 ft respectively. The settings for McAuliffe inlet and outlet are 1.6 ft and 1.25 ft respectively.

Data collection at the McAuliffe RDF was continuously begun starting 25th June 2011. Two major gaps were experienced during data collection in this project. The first data gap was experienced between 12th January 2012 and 6th February 2012 when the McAuliffe Inlet velocity sensor was accidentally damaged during a channel de-silting operation by the Public Works Department, City of McAllen. The second data gap occurred between 8th June 2012 and 10th September 2012 when the water flow to the inlet channel was blocked to aid in the construction of the Coanda-effect screen support structure. Sampling activities were also put on hold during the abovementioned period because the inlet channel was dry.

Morris RDF had a very small stream of continuous inflows on most dry days. The monitoring stations in Morris were setup in July 2011. On 12th August 2011, the velocity sensor setup in the outlet channel was vandalized and the sensor was stolen. The inlet sensor was also damaged and stopped reporting velocity. The sensors were replaced in May 2012. Starting 4th May 2012 the automated samplers at Morris have been set to enable on a level threshold condition.

Appendix B

Hydrographs of inlet and outlet flows for storm events occurring at the McAuliffe and Morris RDFs in McAllen, Texas (2011-2013)

Morris RDF Sampling Hydrographs CY (JUNE 2011-April 2013)

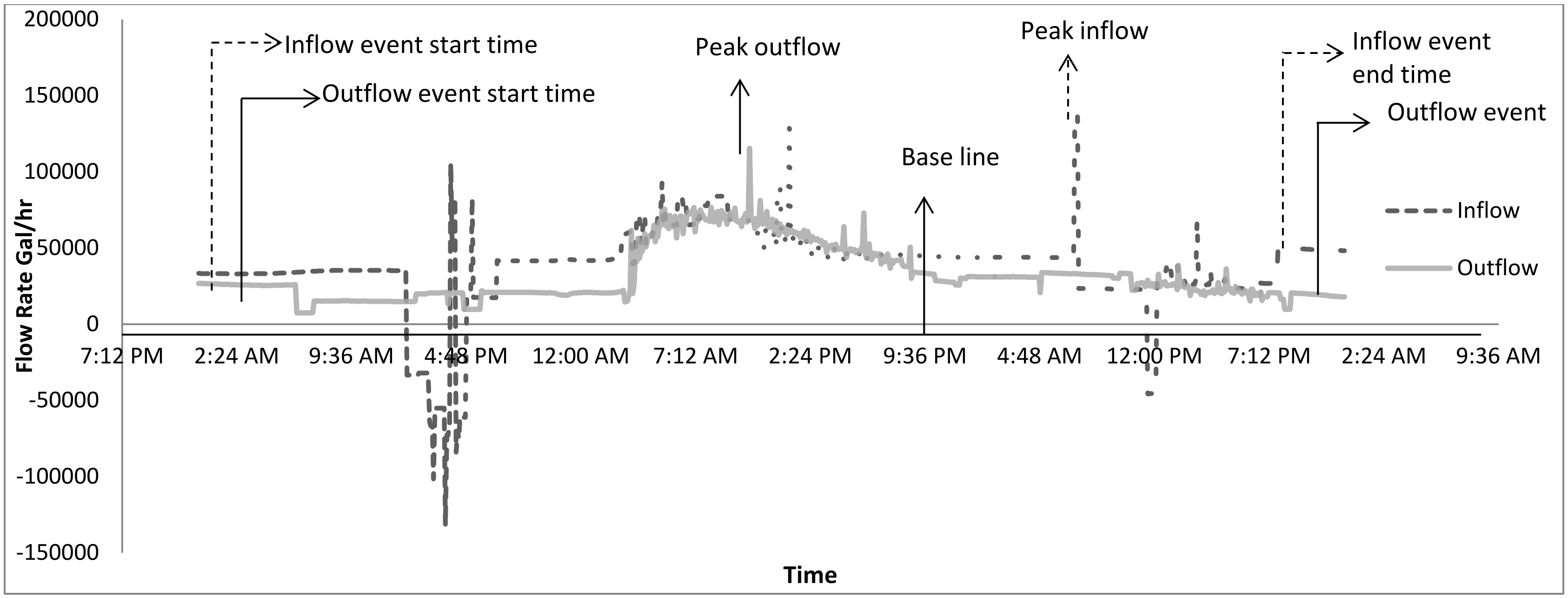


Figure B-1. Plot of inlet and outlet flow for storm event sampled from 06/22/2012 at Morris RDF, McAllen, Tx.

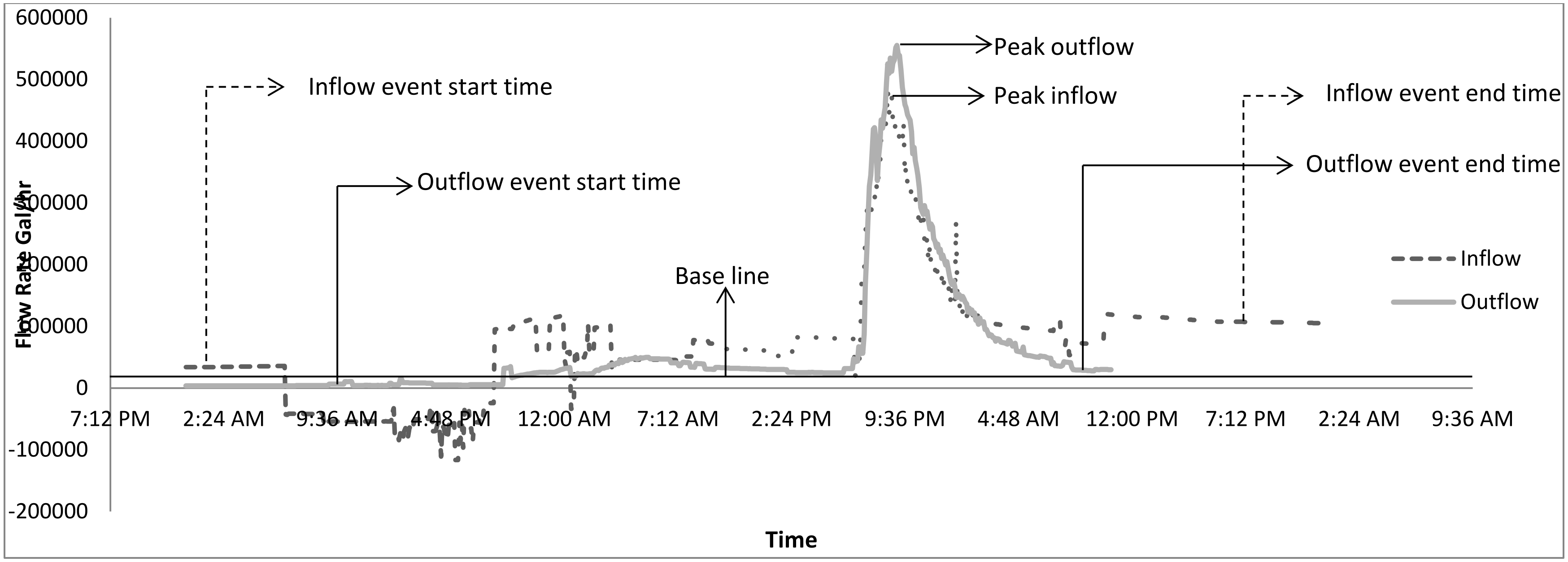


Figure B-2. Plot of inlet and outlet flow for storm event sampled from 07/01/2012 at Morris RDF, McAllen, Tx.

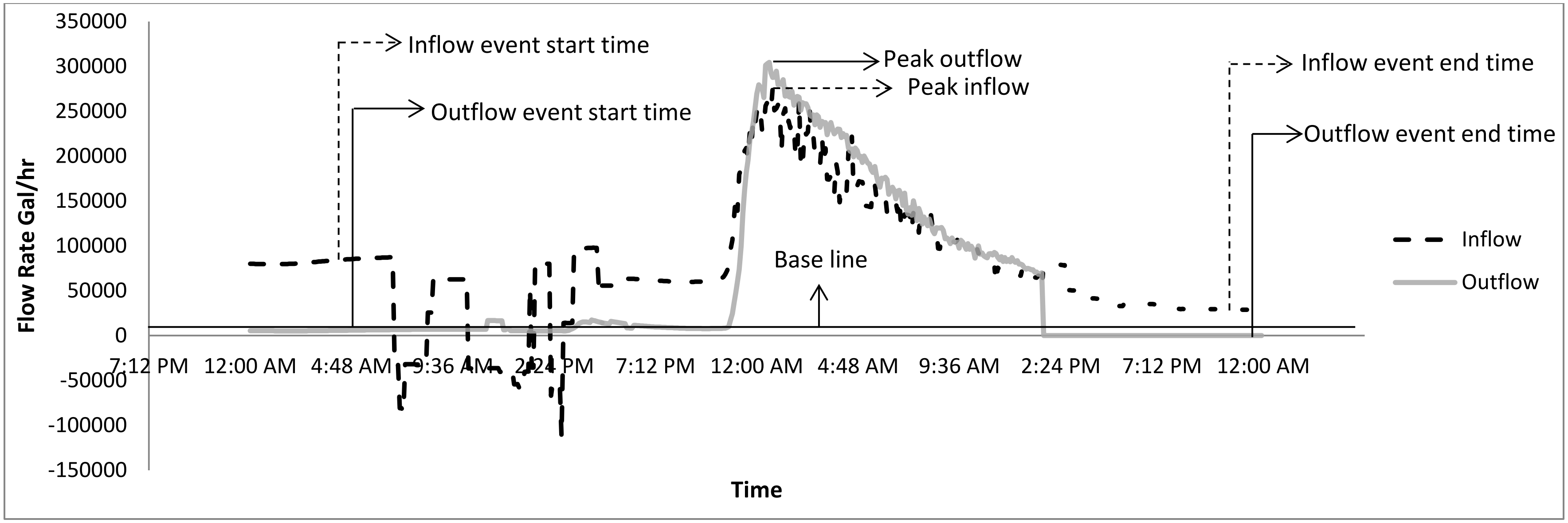


Figure B-3. Plot of inlet and outlet flow for storm event sampled from 07/19/2012 at Morris RDF, McAllen, Tx.

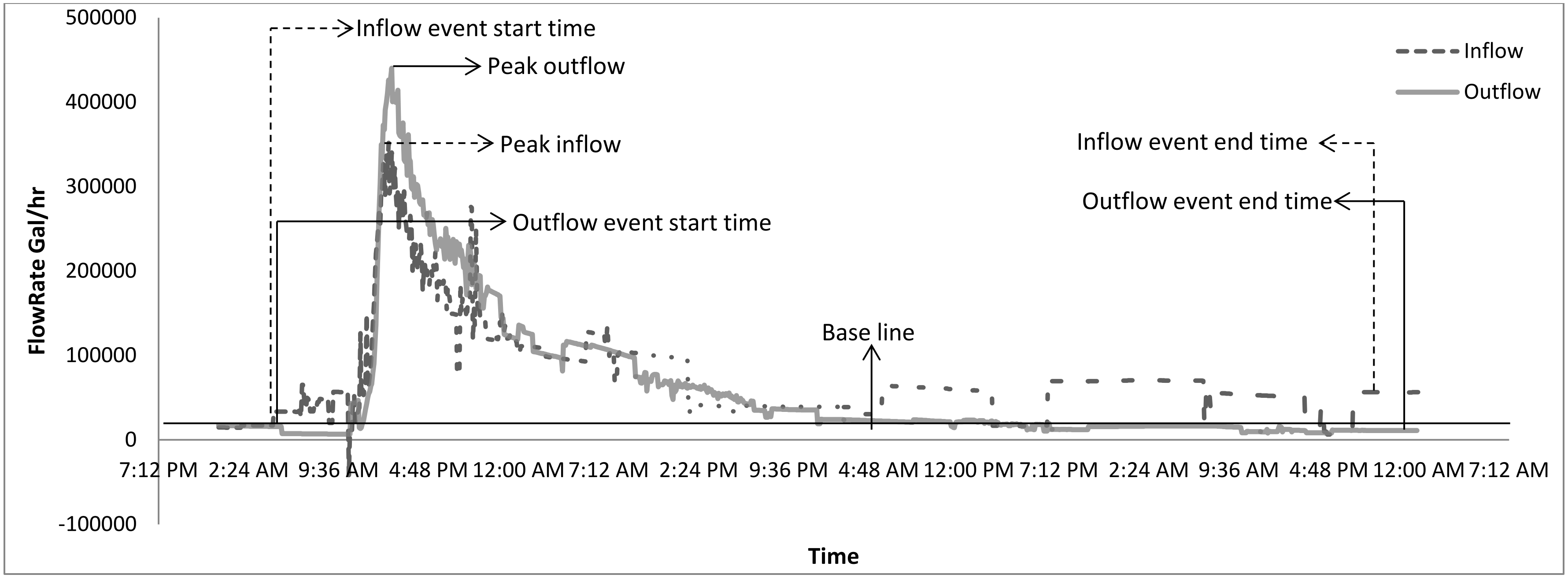


Figure B-4. Plot of inlet and outlet flow for storm event sampled from 09/01/2012 at Morris RDF, McAllen, Tx.

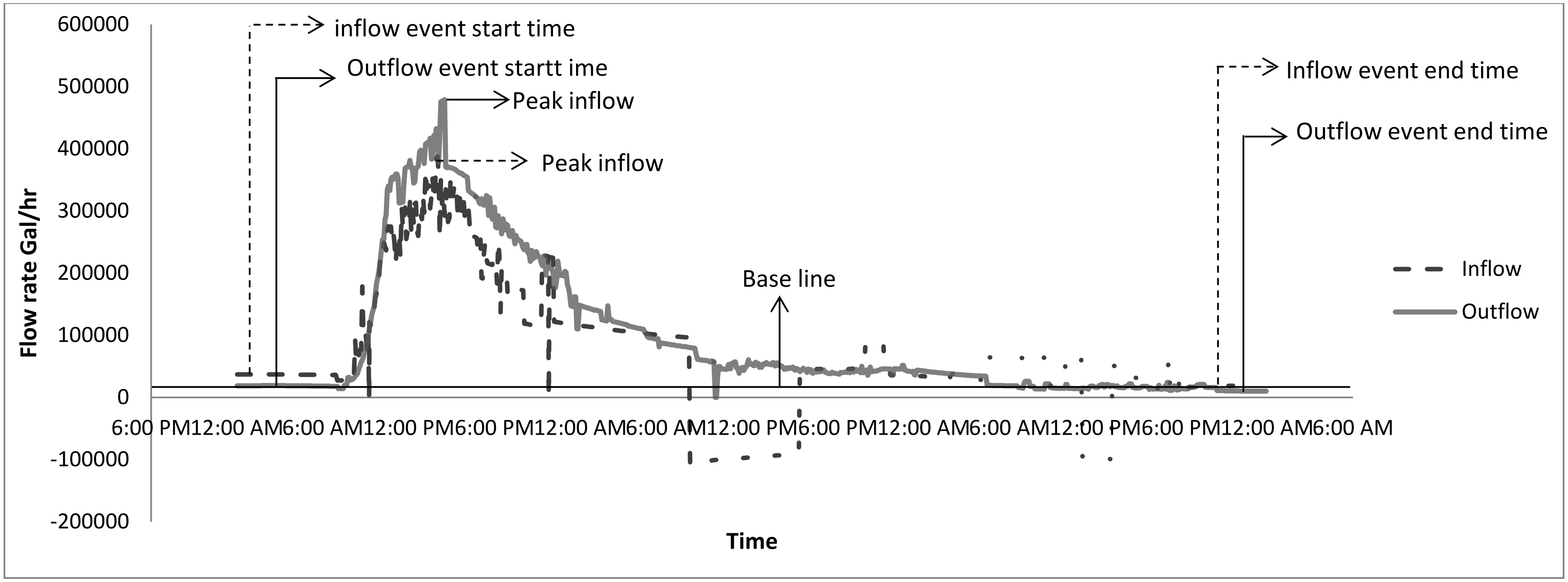


Figure B-5. Plot of inlet and outlet flow for storm event sampled from 09/09/2012 at Morris RDF, McAllen, Tx.

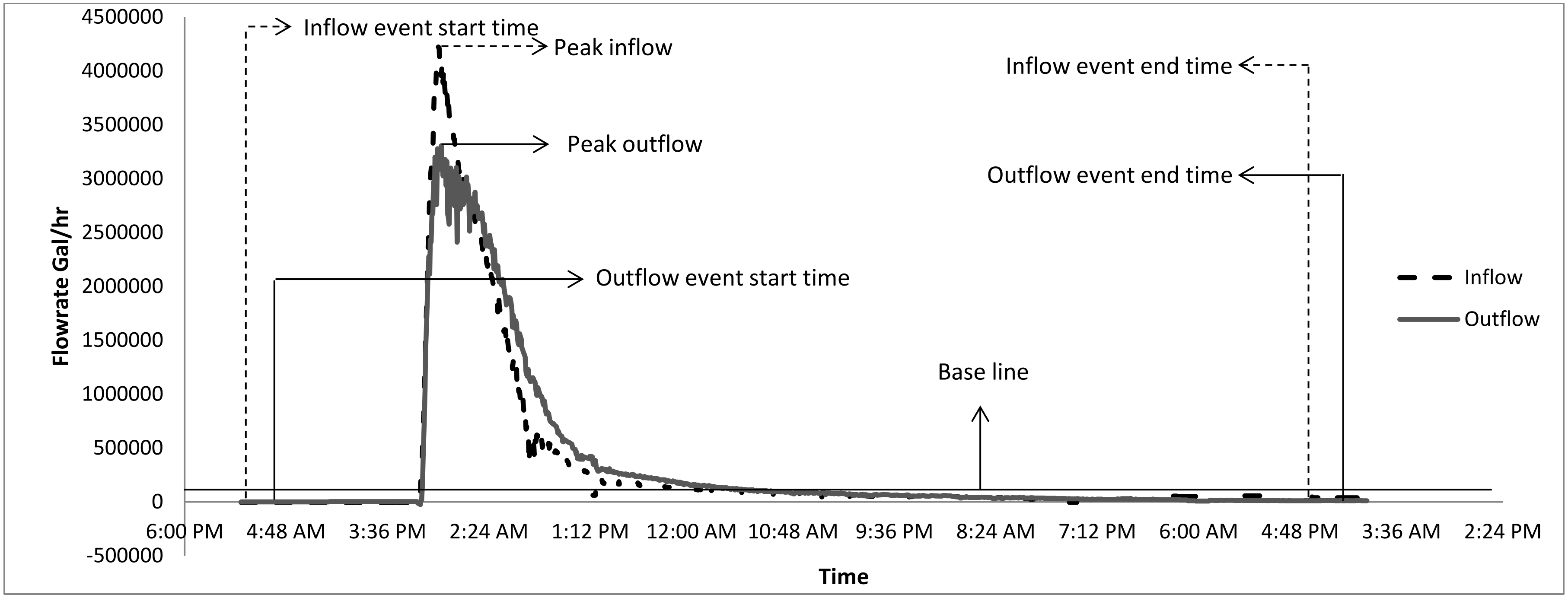


Figure B-6. Plot of inlet and outlet flow for storm event sampled from 10/18/2012 at Morris RDF, McAllen, Tx.

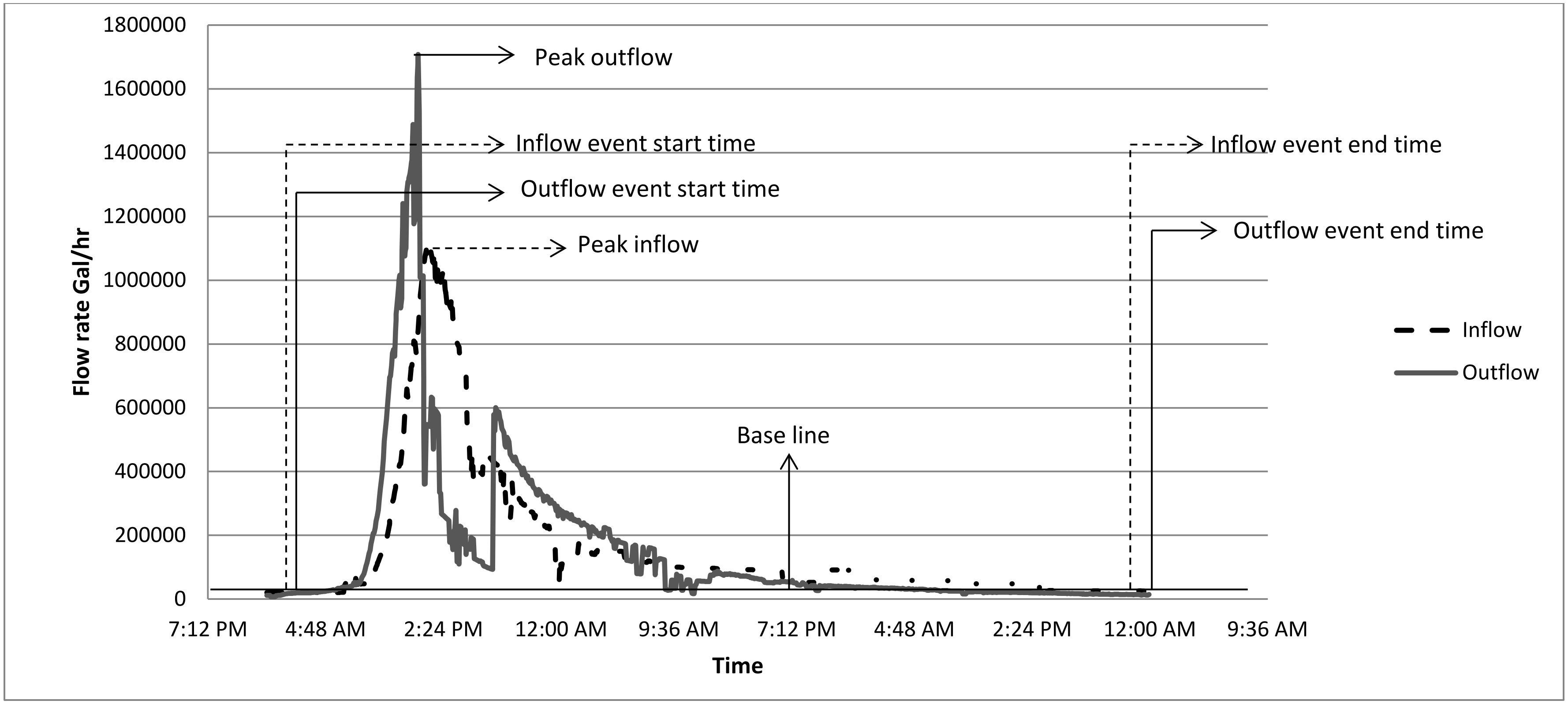


Figure B-7. Plot of inlet and outlet flow for storm event sampled from 01/09/2013 at Morris RDF, McAllen, Tx.

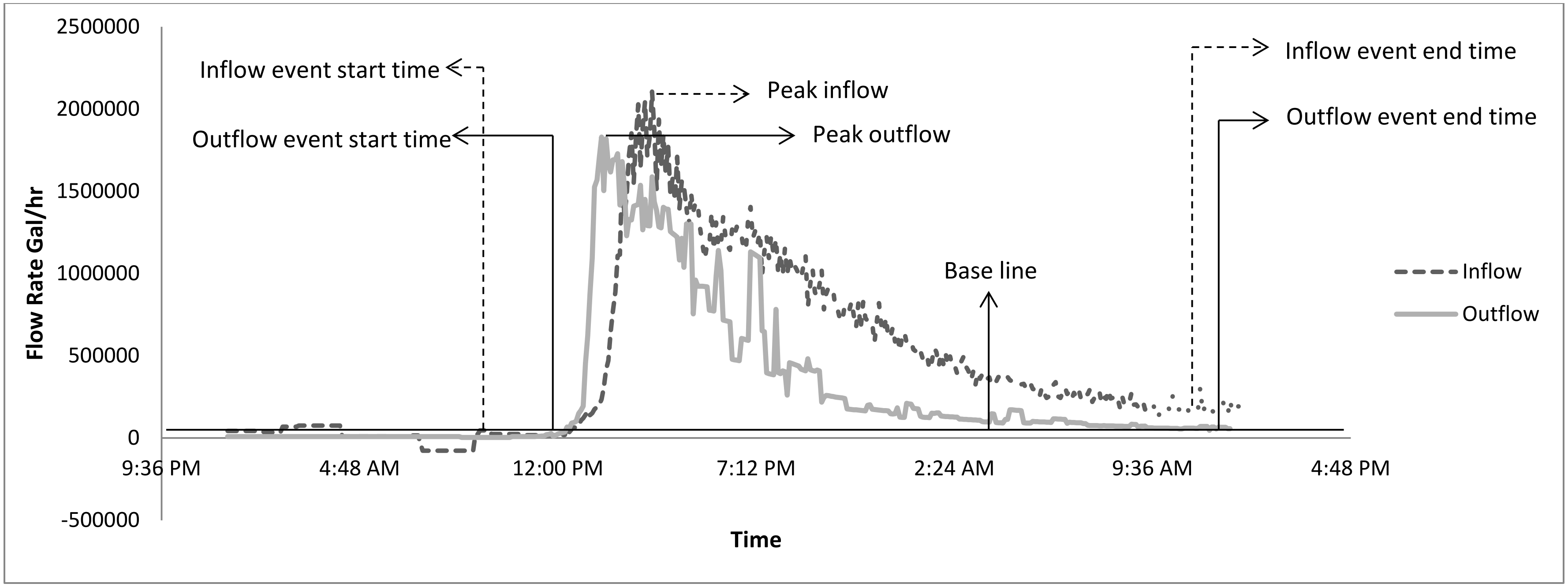


Figure B-8. Plot of inlet and outlet flow for storm event sampled from 04/28/2013 at Morris RDF, McAllen, Tx.

Morris RDF for Estimated Events CY (JUNE 2011-October 2012)

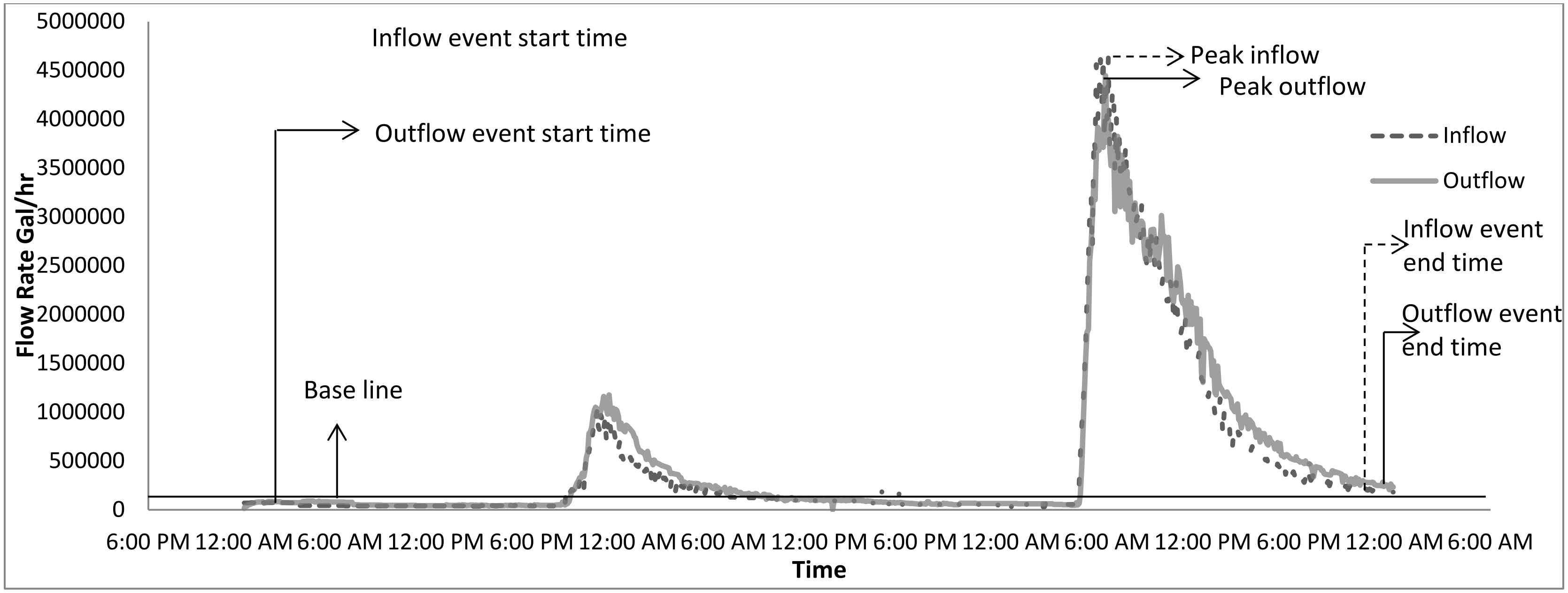


Figure B-9. Plot of inlet and outlet flow for estimated storm event on 05/09/2012 at Morris RDF, McAllen, Tx.

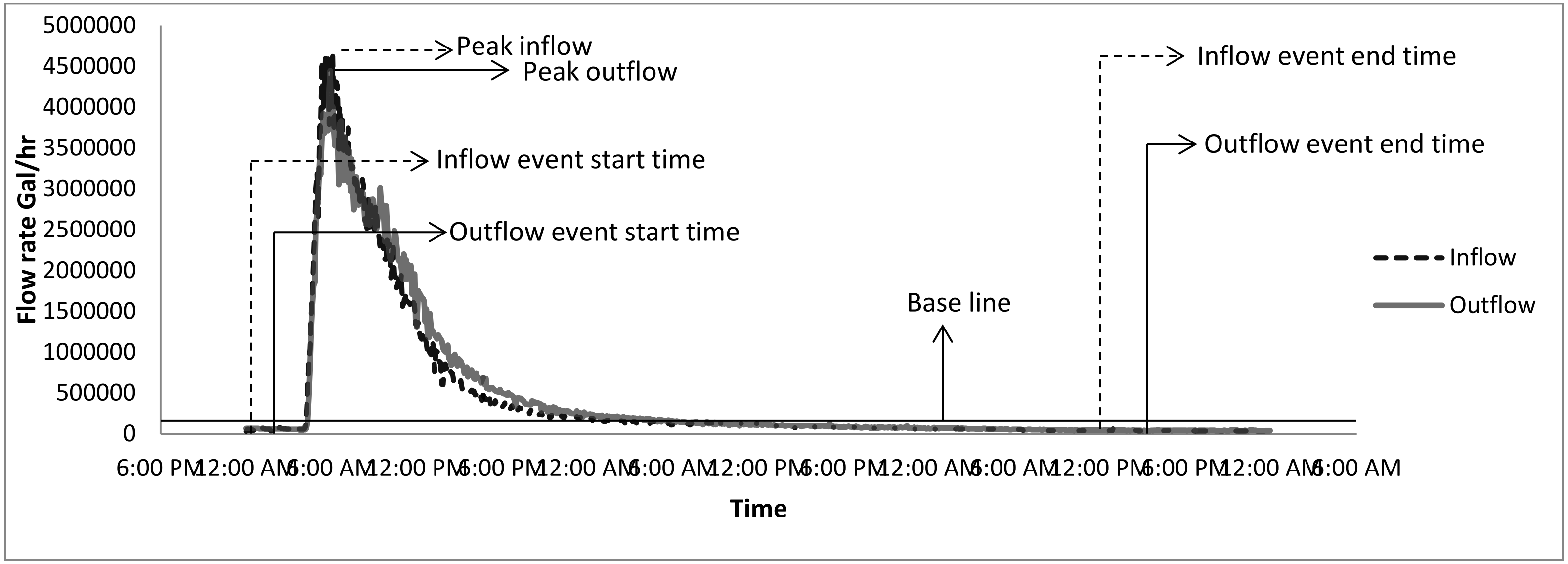


Figure B-10. Plot of inlet and outlet flow for estimated storm event on 05/11/2012 at Morris RDF, McAllen, Tx.

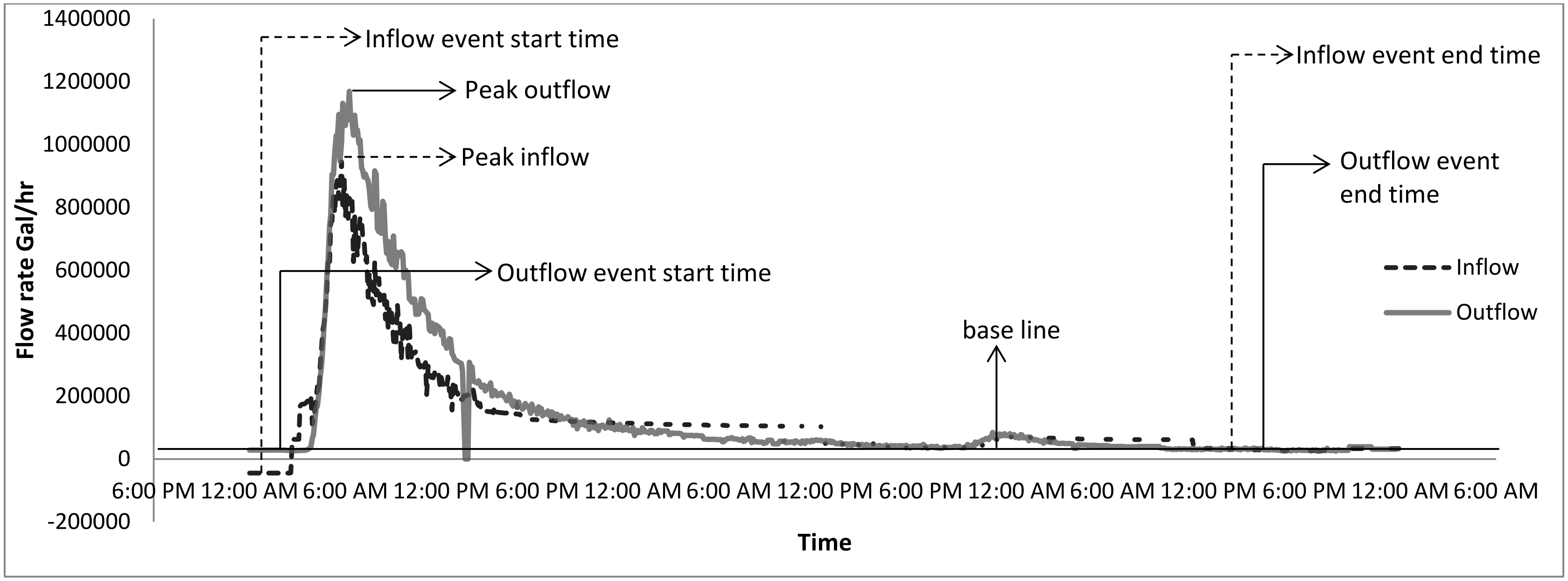


Figure B-11. Plot of inlet and outlet flow for estimated storm event on 05/15/2012 at Morris RDF, McAllen, Tx.

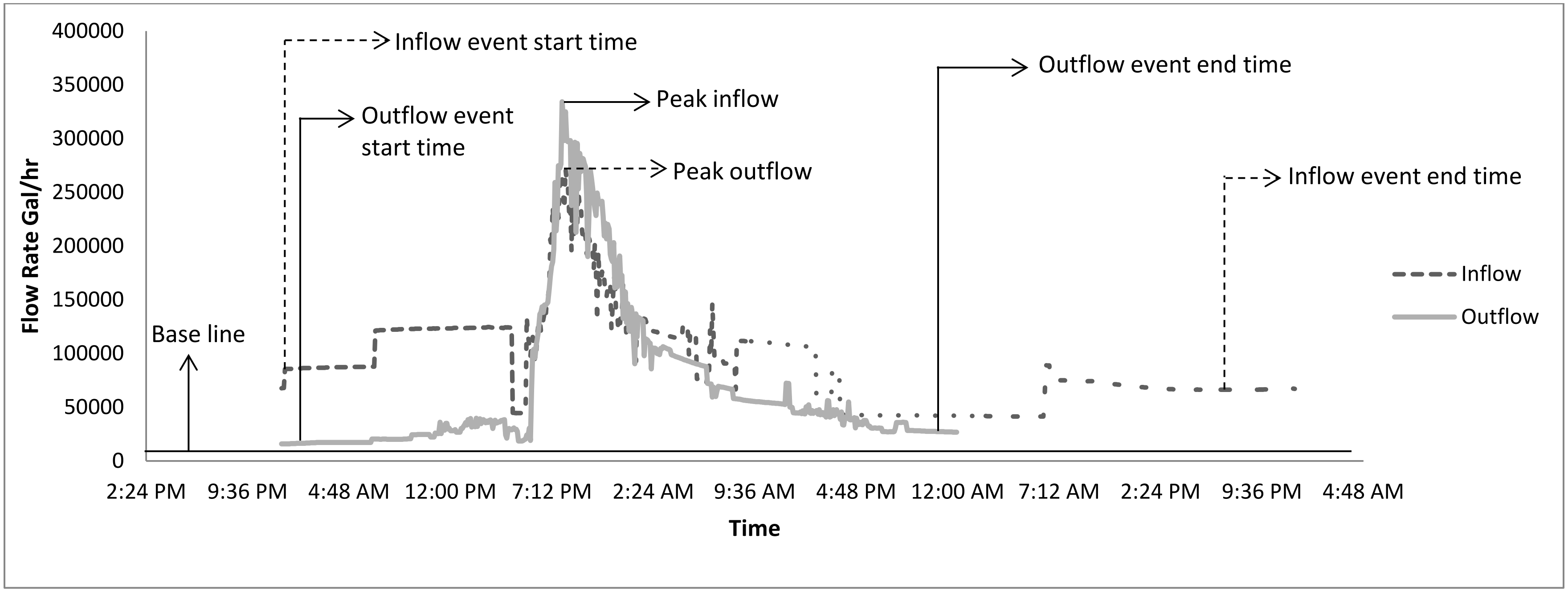


Figure B-12. Plot of inlet and outlet flow for estimated storm event on 06/08/2012 at Morris RDF, McAllen, Tx.

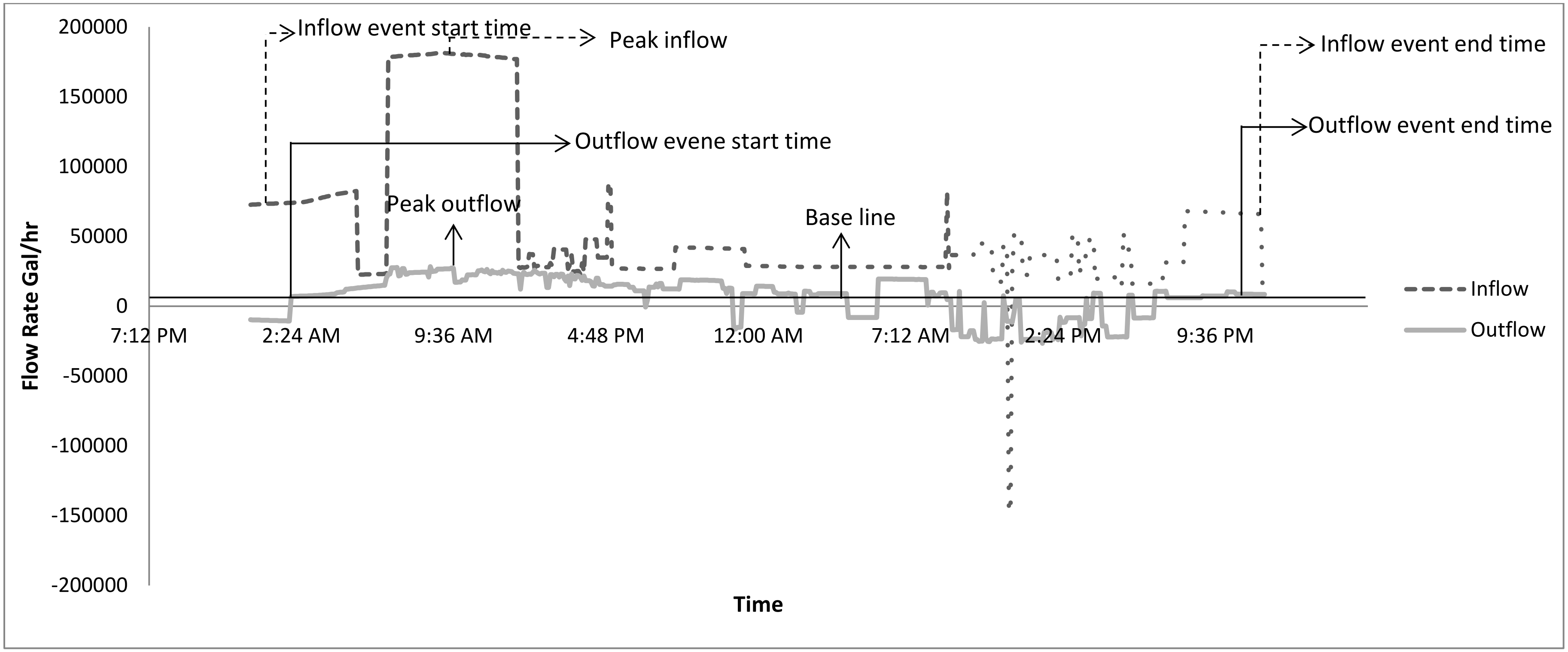


Figure B-13. Plot of inlet and outlet flow for estimated storm event on 08/14/2012 at Morris RDF, McAllen, Tx.

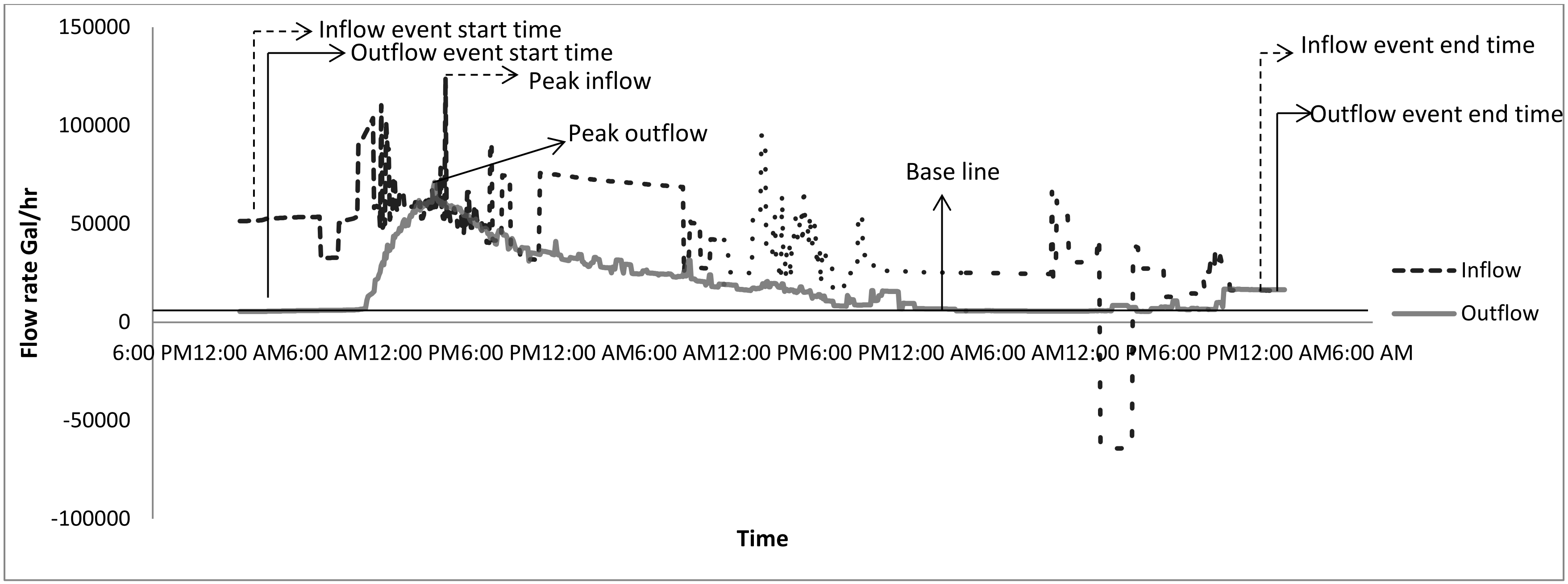


Figure B-14. Plot of inlet and outlet flow for estimated storm event on 08/20/2012 at Morris RDF, McAllen, Tx.

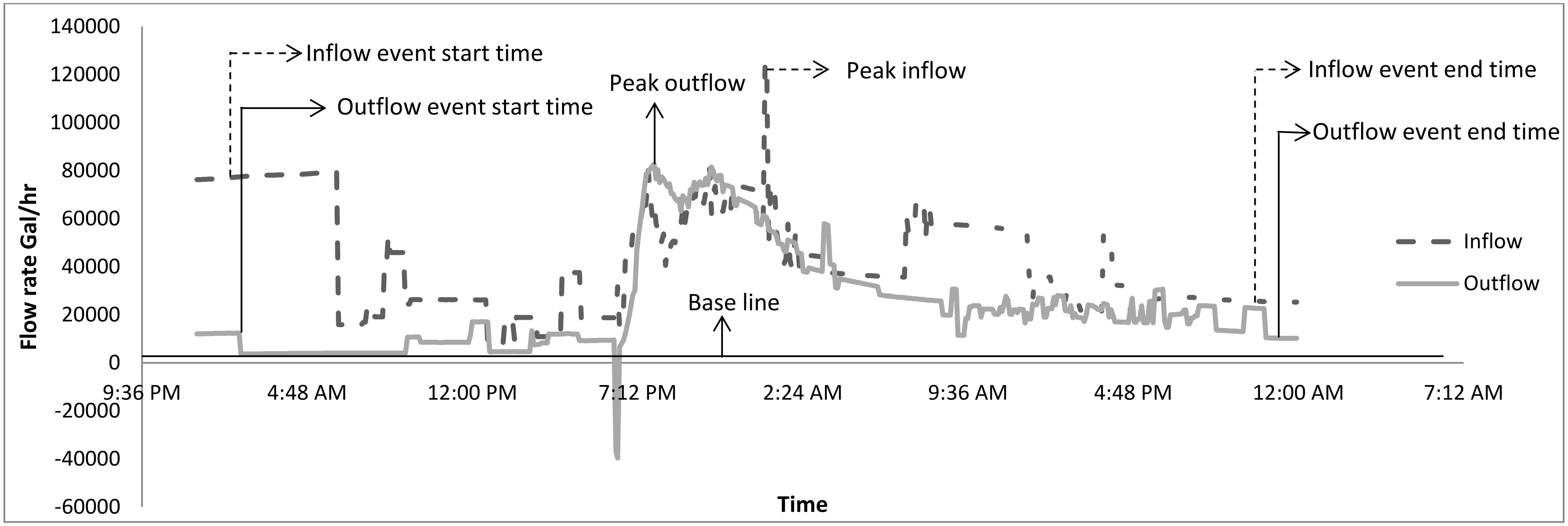


Figure B-15. Plot of inlet and outlet flow for estimated storm event on 08/28/2012 at Morris RDF, McAllen, Tx.

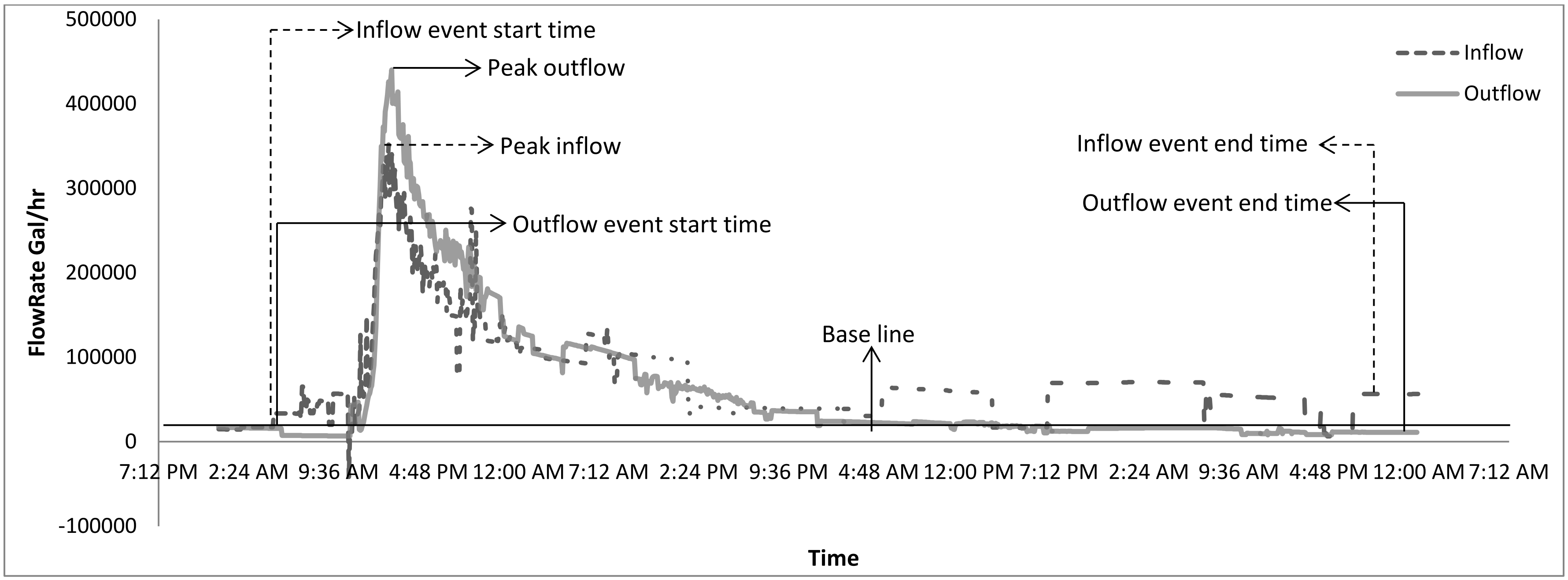


Figure B-16. Plot of inlet and outlet flow for estimated storm event on 09/01/2012 at Morris RDF, McAllen, Tx.

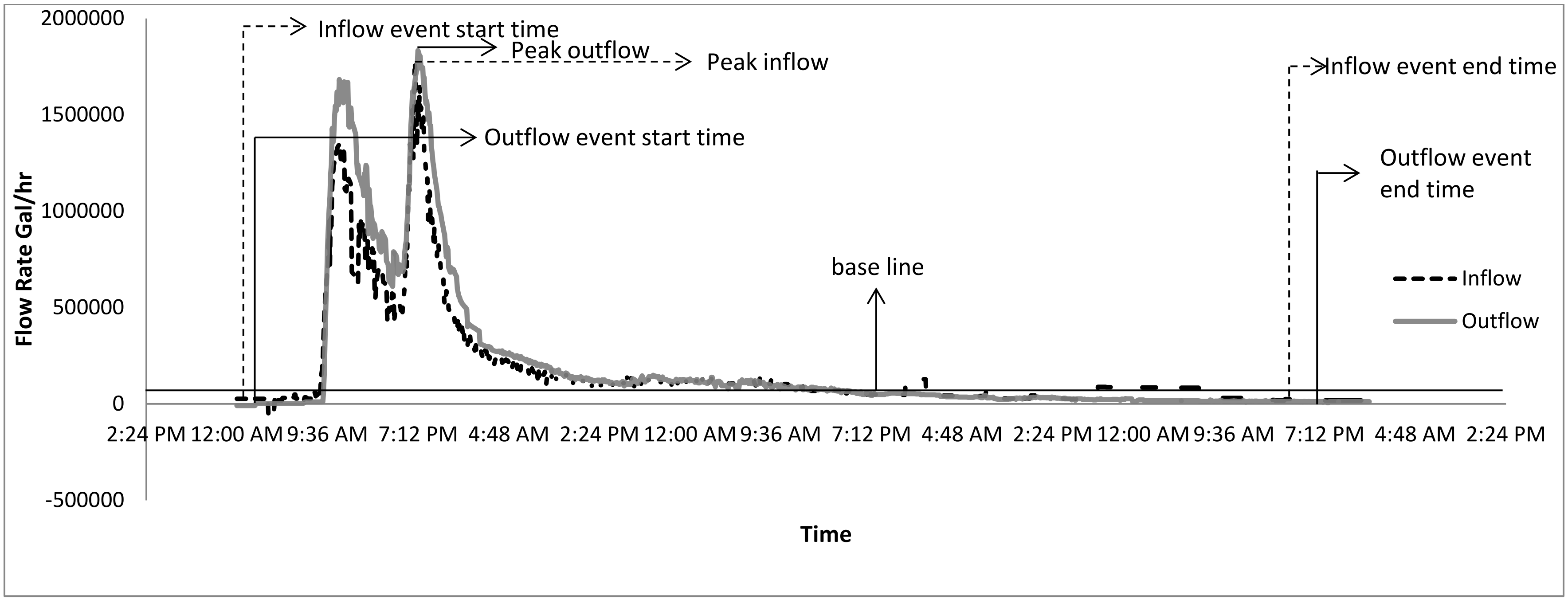


Figure B-17. Plot of inlet and outlet flow for estimated storm event on 09/14/2012 at Morris RDF, McAllen, Tx.

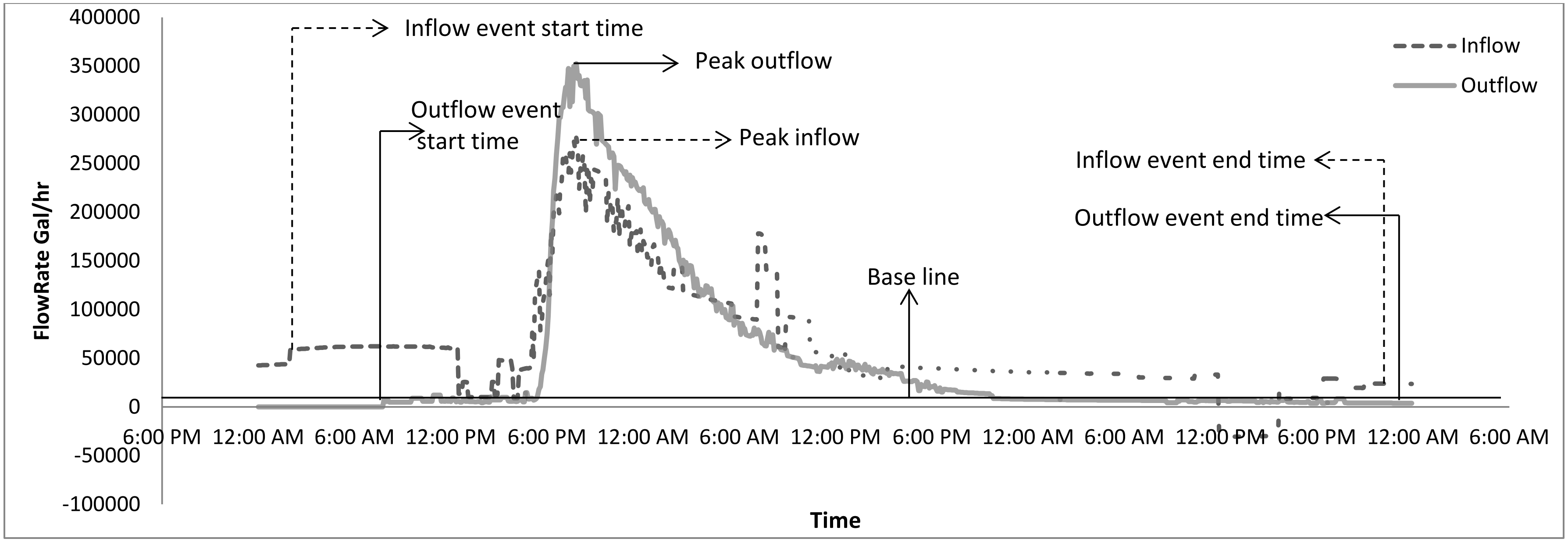


Figure B-18. Plot of inlet and outlet flow for estimated storm event on 09/23/2012 at Morris RDF, McAllen, Tx.

McAuliffe RDF Sampling Hydrographs CY (JUNE 2011-April 2013)

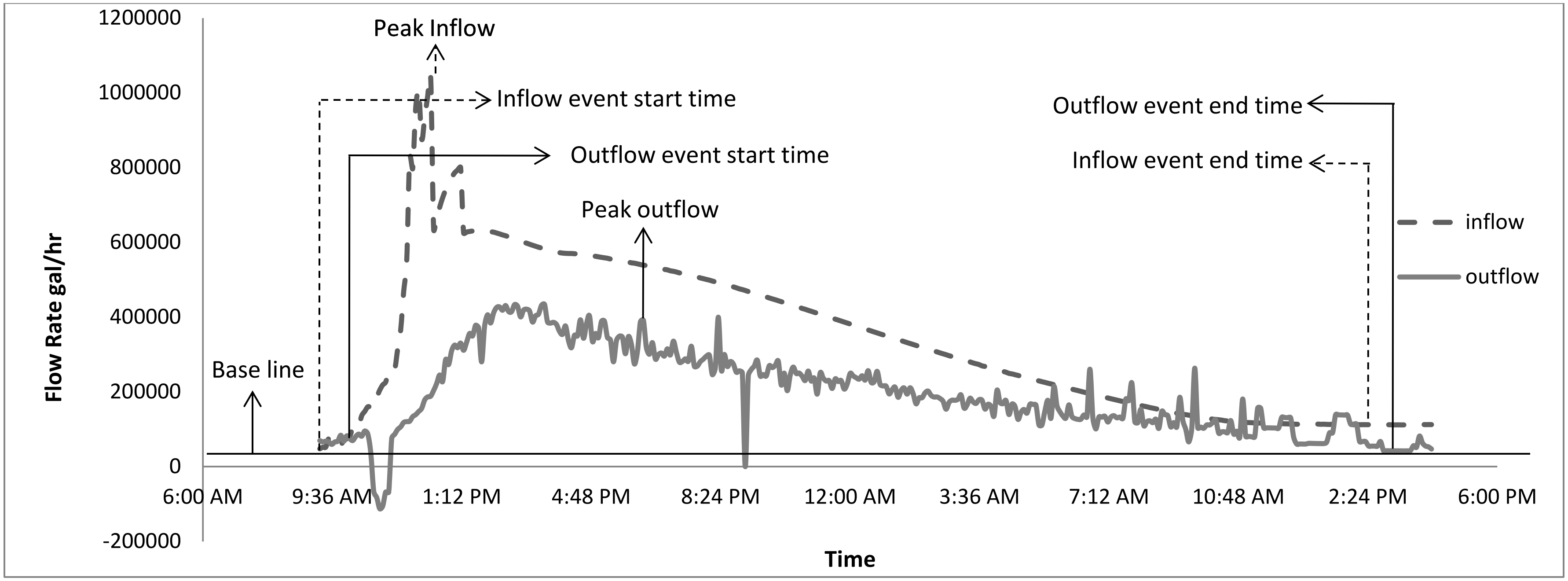


Figure B-19. Plots of inlet and outlet flow for storm event sampled from 06/28/2011 at McAuliffe RDF, McAllen, TX.

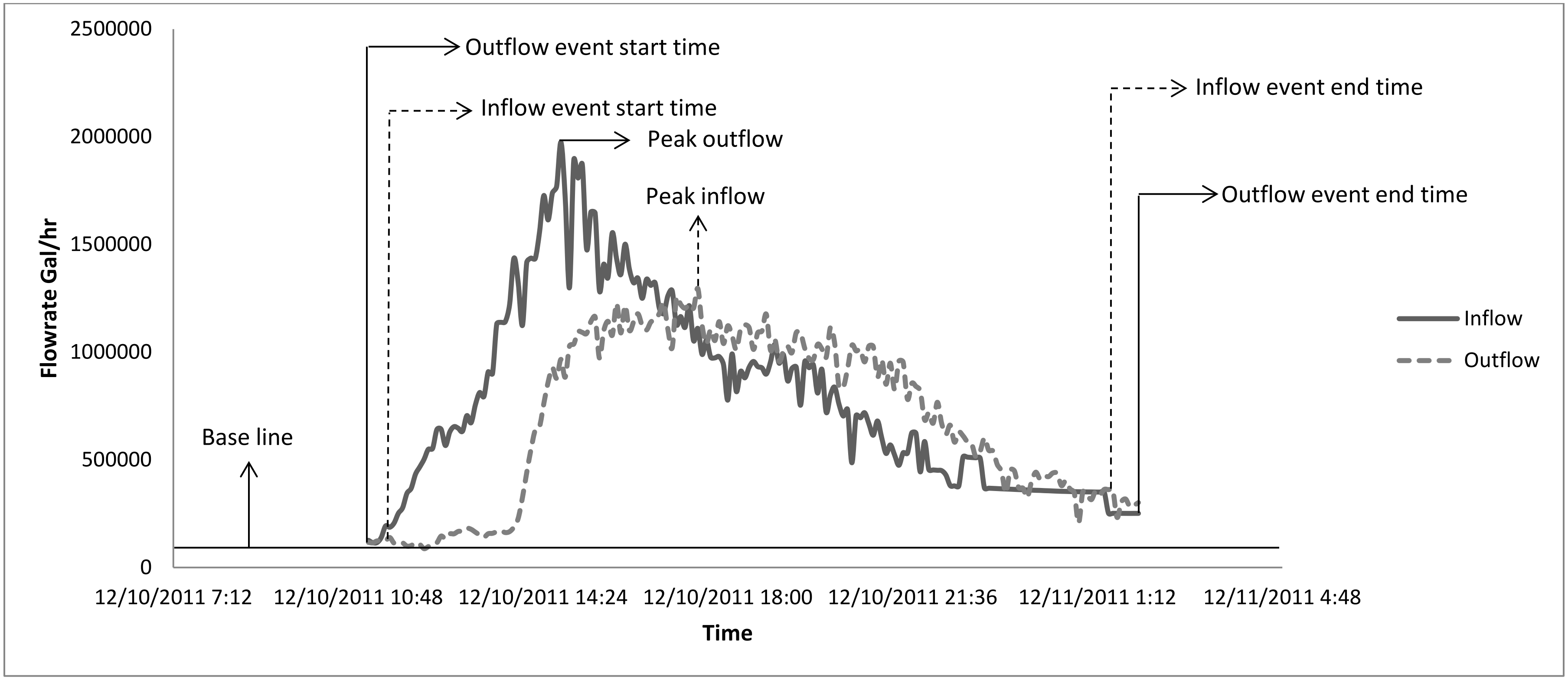


Figure B-20. Plots of inlet and outlet flow for storm event sampled from 12/10/2011 at McAuliffe RDF, McAllen, TX.

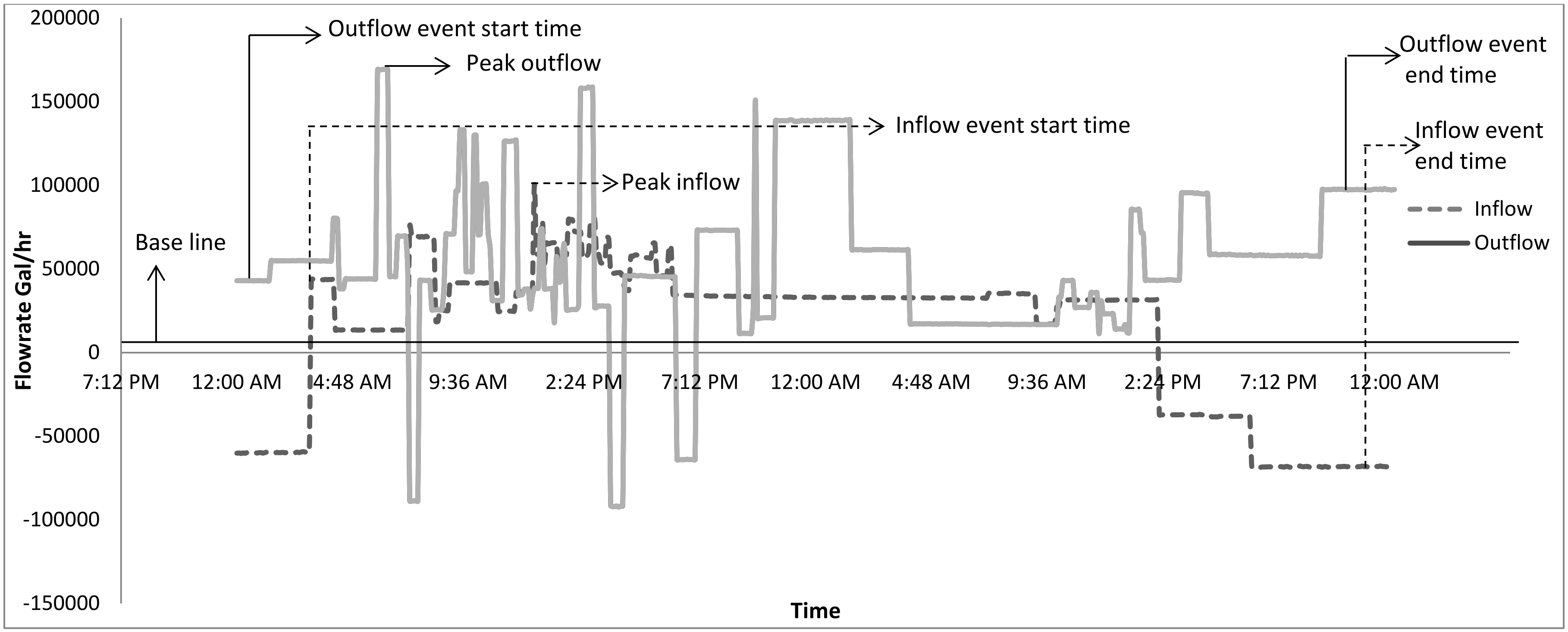


Figure B-21. Plots of inlet and outlet flow for storm event sampled from 12/19/2011 at McAuliffe RDF, McAllen, TX.

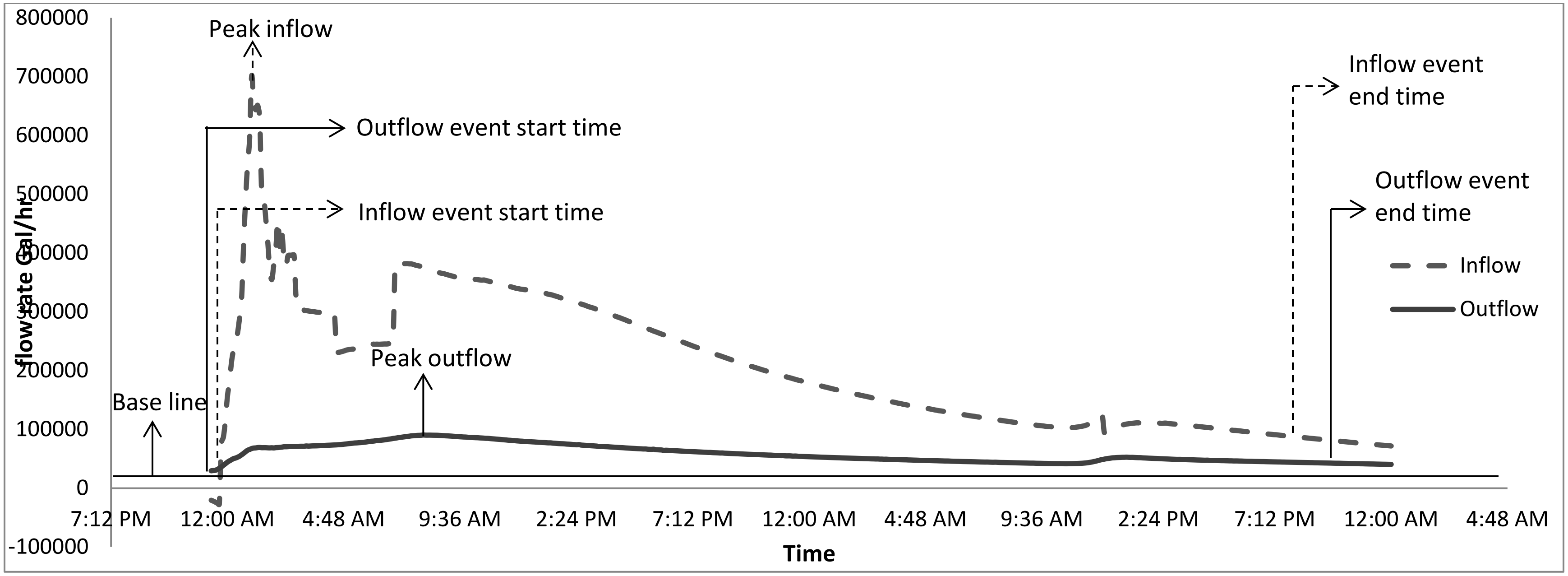


Figure B-22. Plots of inlet and outlet flow for storm event sampled from 02/08/2012 at McAuliffe RDF, McAllen, TX.

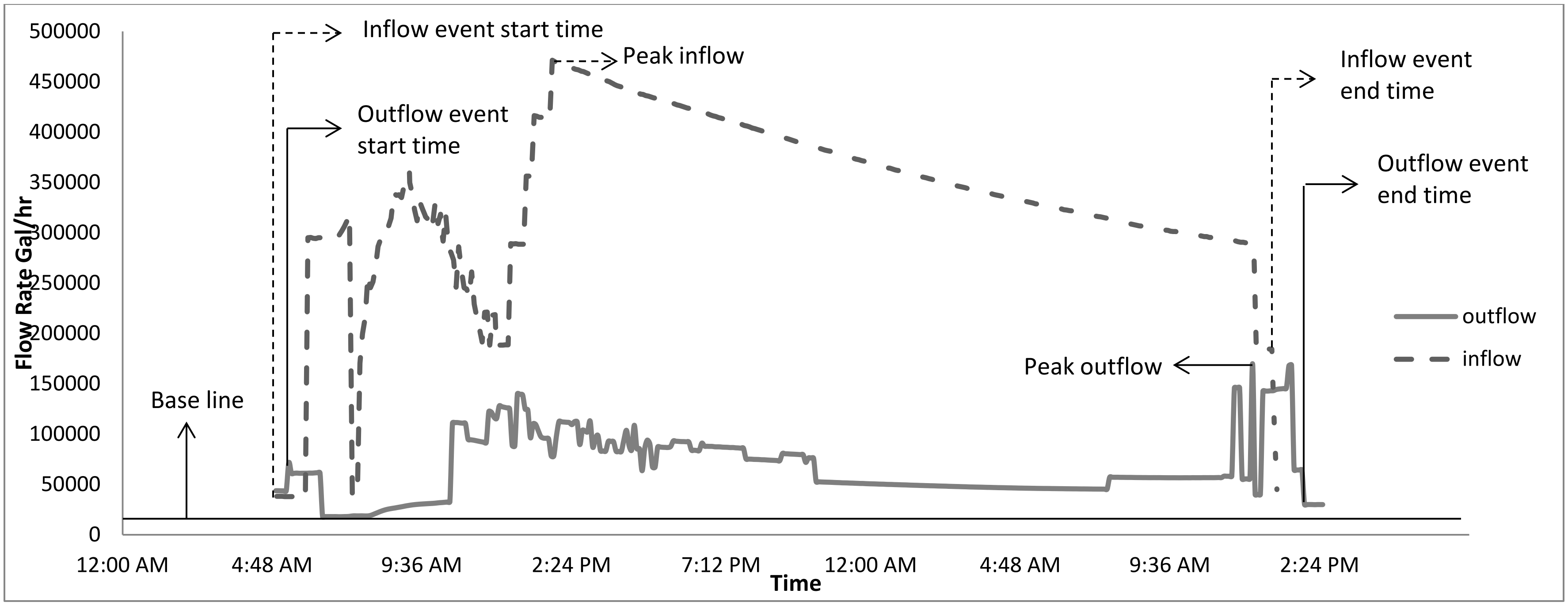


Figure B-23. Plots of inlet and outlet flow for storm event sampled from 01/09/2013 at McAuliffe RDF, McAllen, TX.

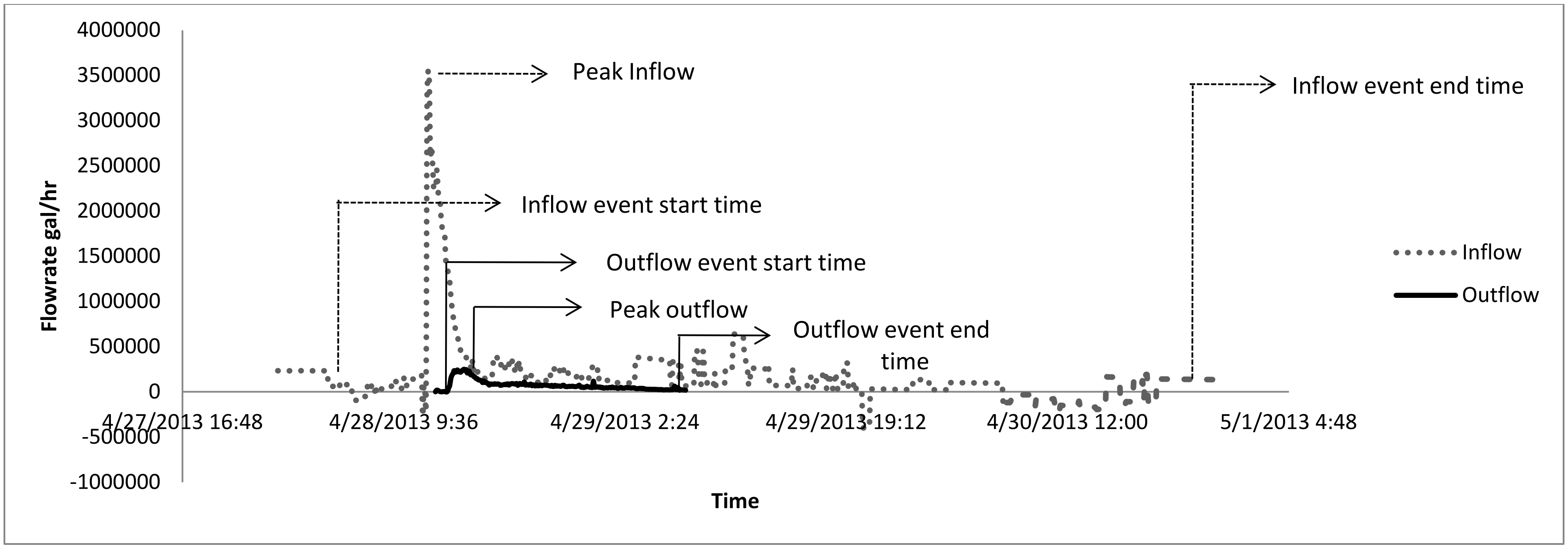


Figure B-24. Plots of inlet and outlet flow for storm event sampled from 04/28/2013 at McAuliffe RDF, McAllen, TX.

McAuliffe RDF Hydrographs for Estimated Events CY (JUNE 2011-October 2012)

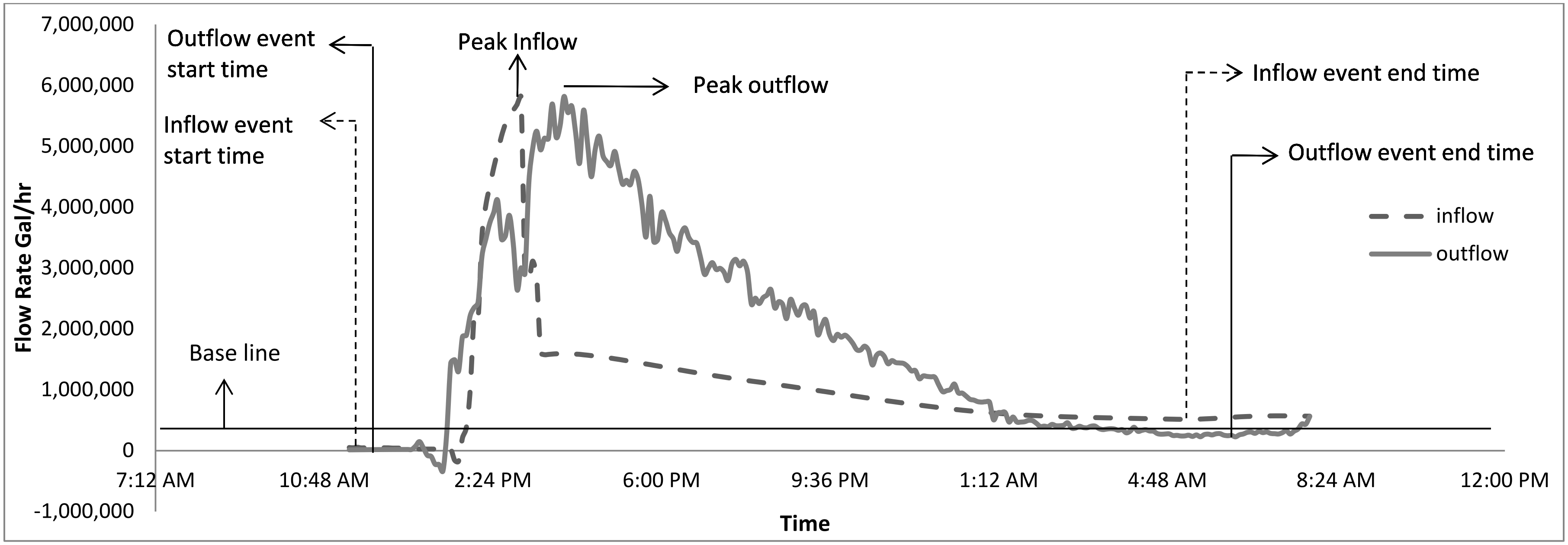


Figure B-25. Plots of inlet and outlet flow for estimated storm event on 06/22/2011 at McAuliffe RDF, McAllen, TX.

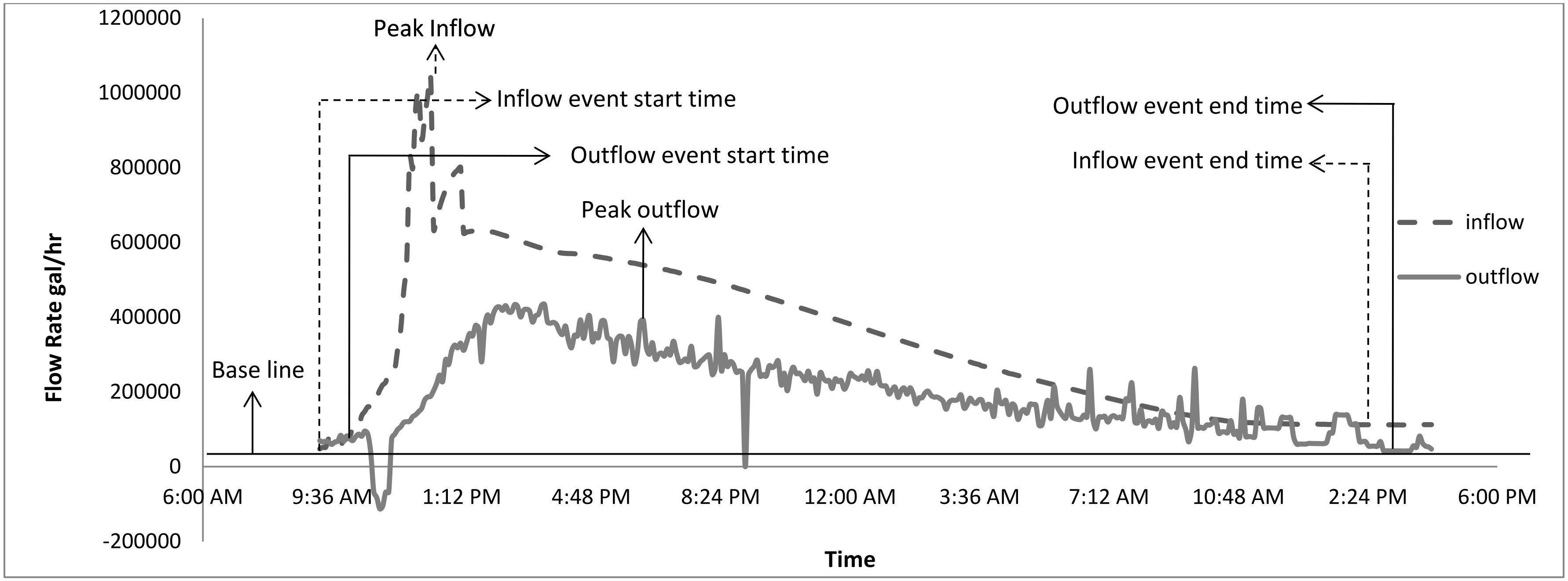


Figure B-26. Plots of inlet and outlet flow for estimated storm event on 06/30/2011 at McAuliffe RDF, McAllen, TX.

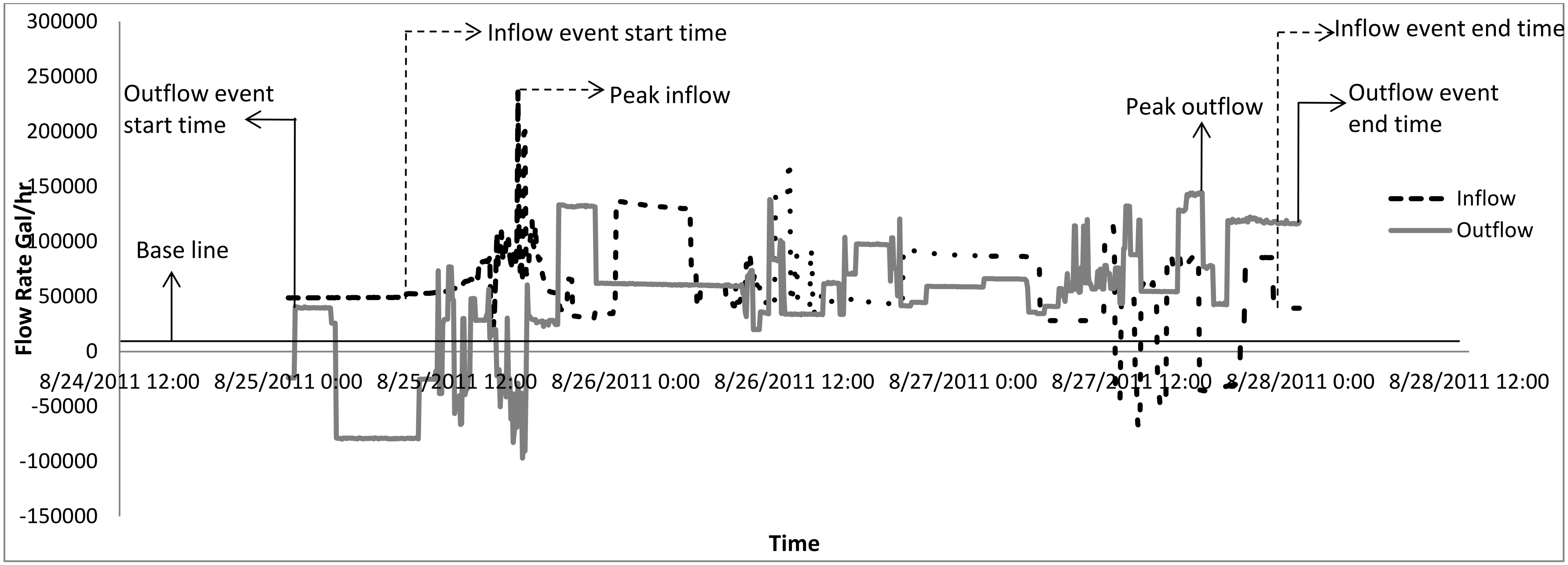
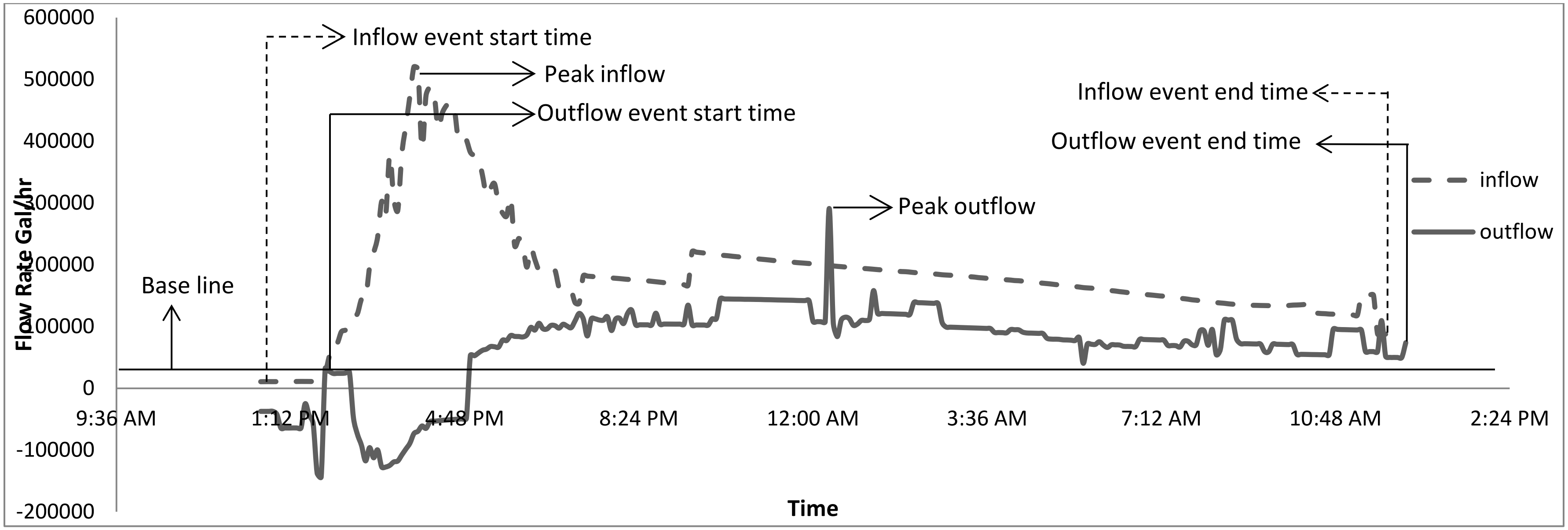


Figure B-27. Plots of inlet and outlet flow for estimated storm event on 08/25/2011 at McAuliffe RDF, McAllen, TX.



FigureB-28. Plots of inlet and outlet flow for estimated storm event on 10/01/2011 at McAuliffe RDF, McAllen, TX.

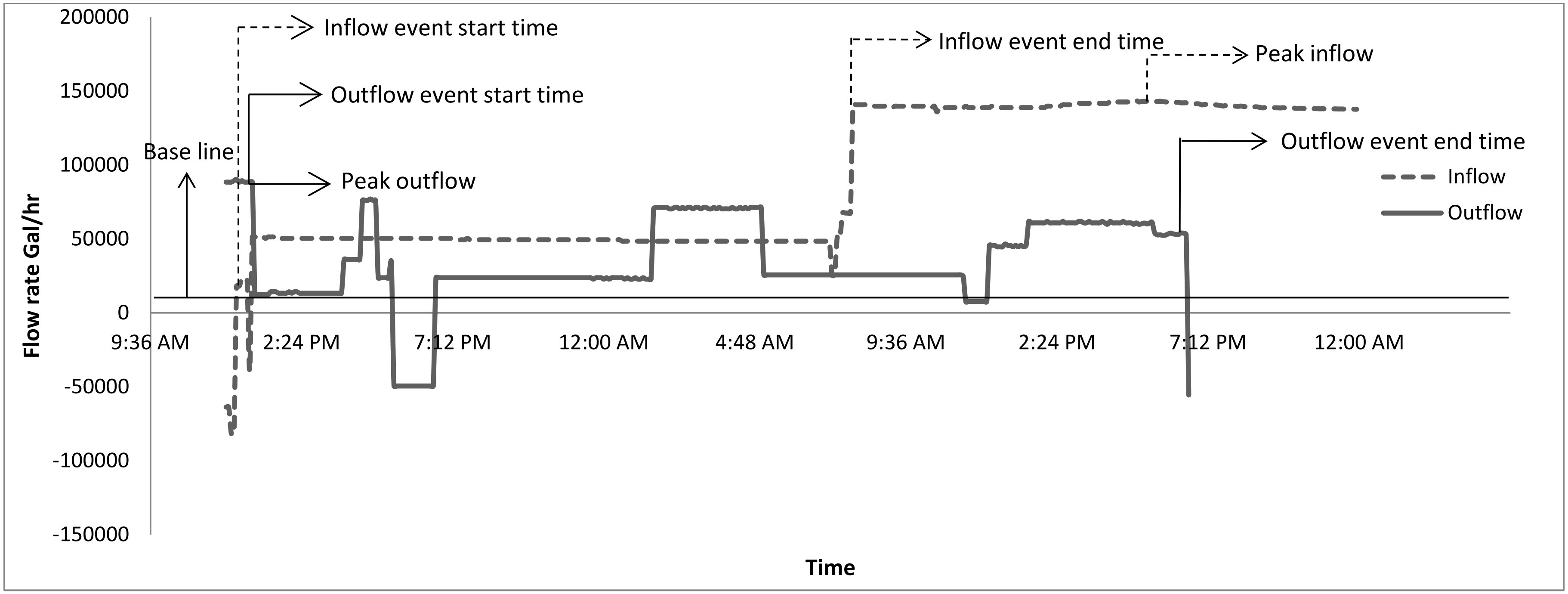


Figure B-29. Plots of inlet and outlet flow for estimated storm event on 11/03/2011 at McAuliffe RDF, McAllen, TX.

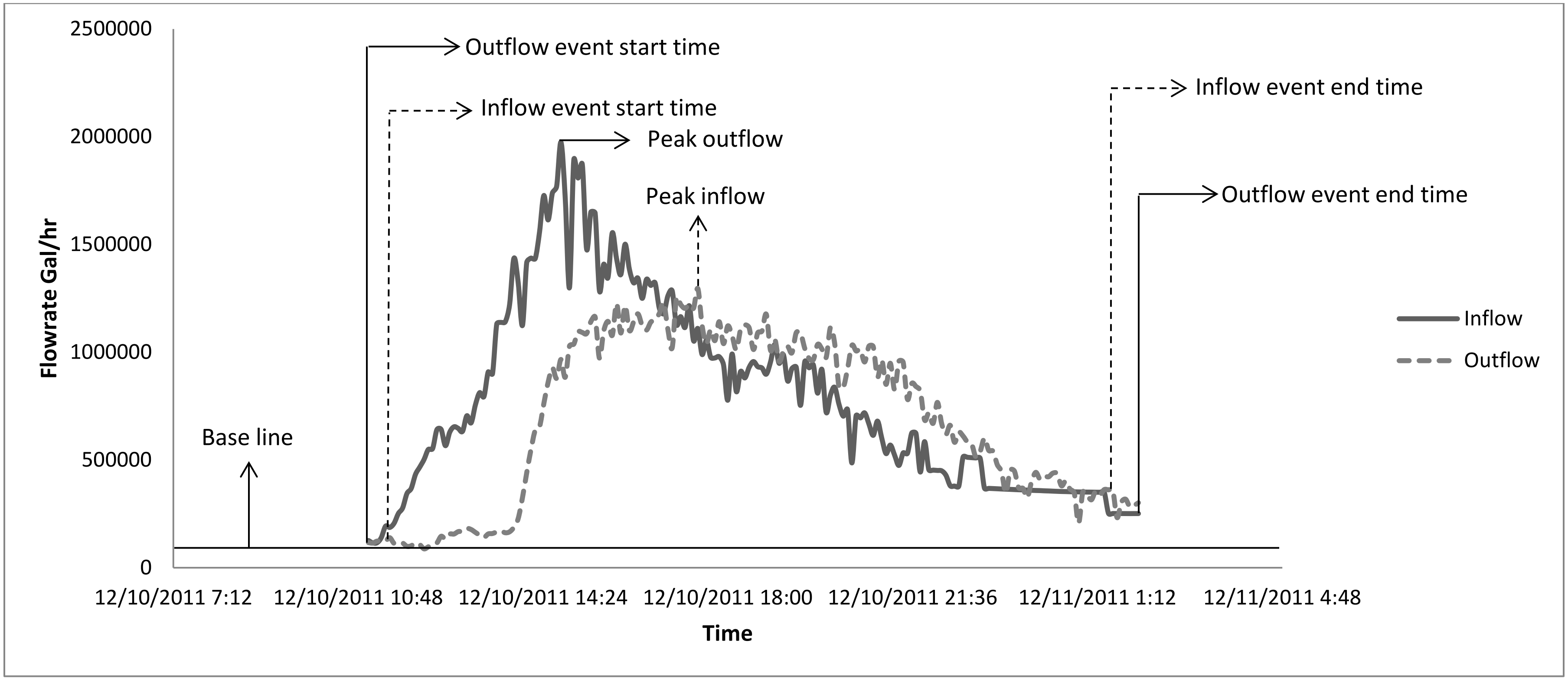


Figure B-30. Plots of inlet and outlet flow for estimated storm event on 12/10/2011 at McAuliffe RDF, McAllen, TX.

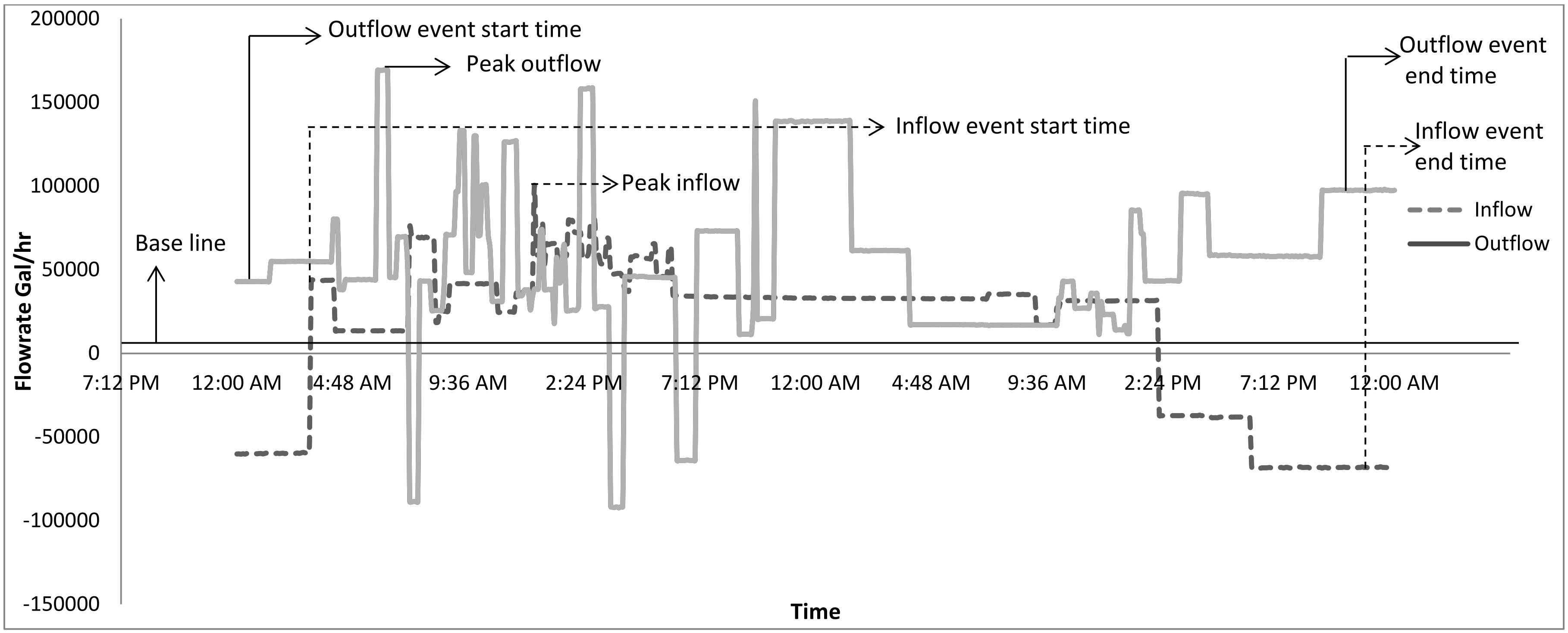


Figure B-31. Plots of inlet and outlet flow for estimated storm event on 12/19/2011 at McAuliffe RDF, McAllen, TX.

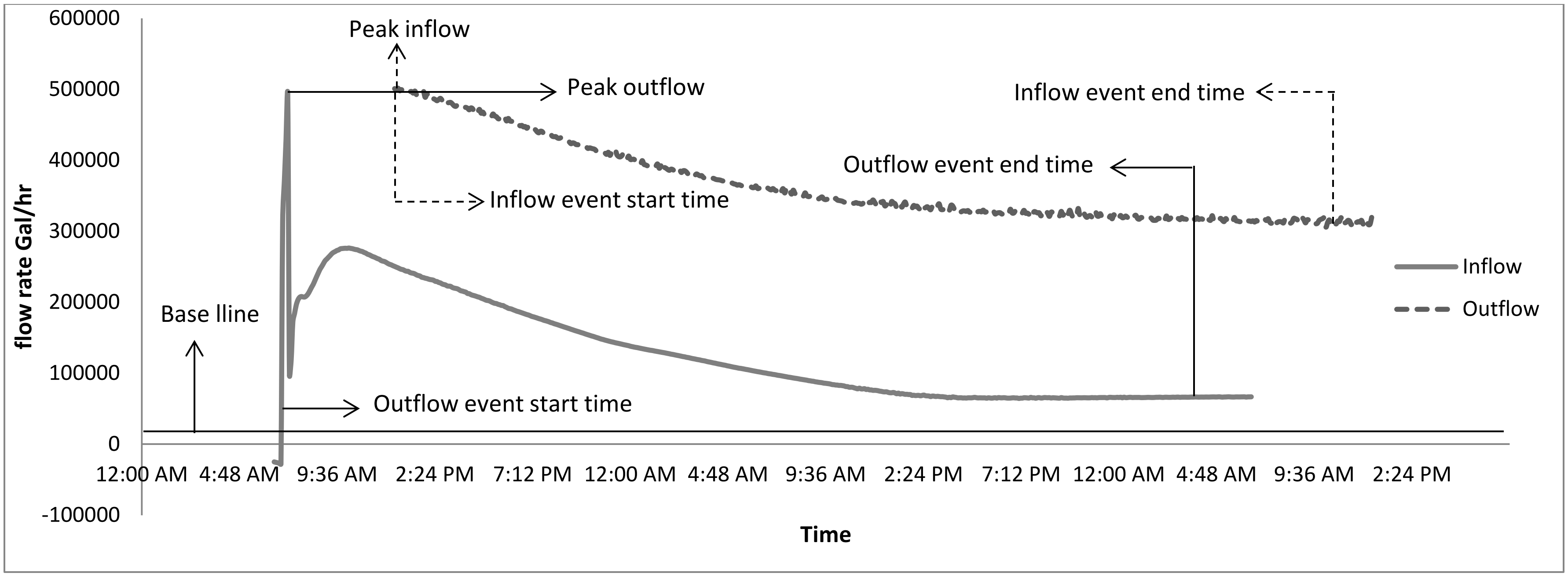


Figure B-32. Plots of inlet and outlet flow for estimated storm event on 02/05/2012 at McAuliffe RDF, McAllen, TX.

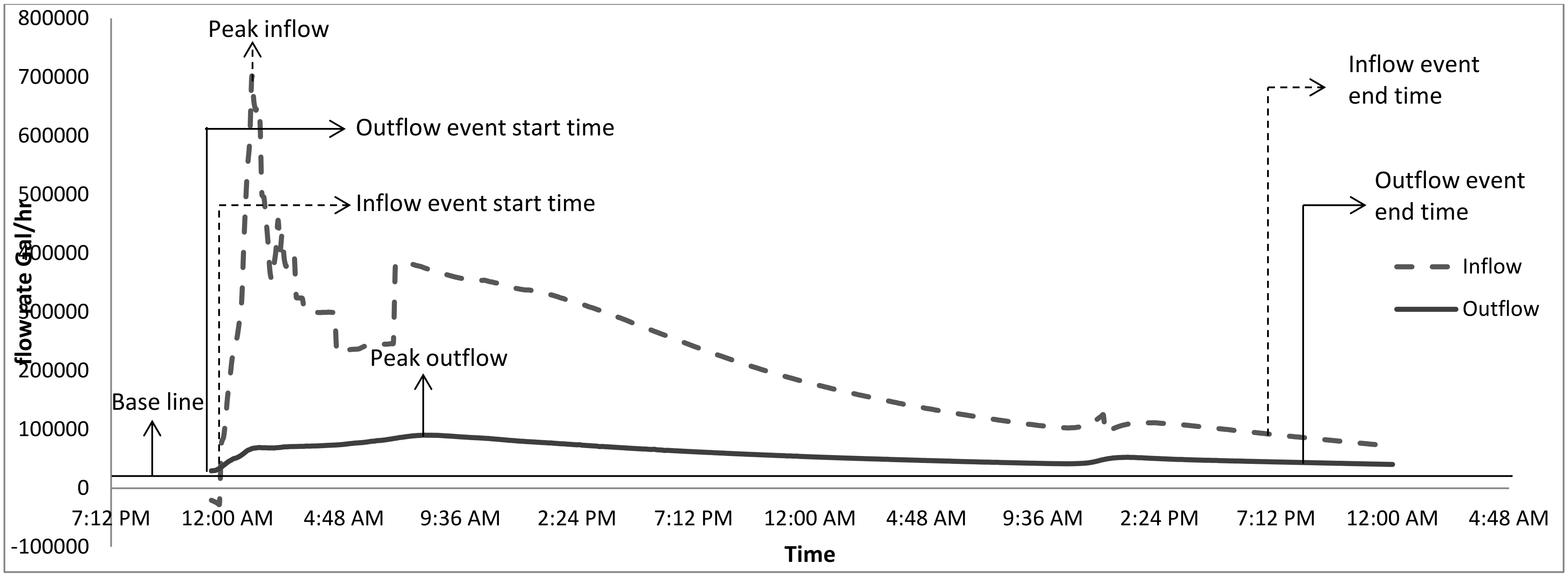


Figure B-33. Plots of inlet and outlet flow for estimated storm event on 02/07/2012 at McAuliffe RDF, McAllen, TX.

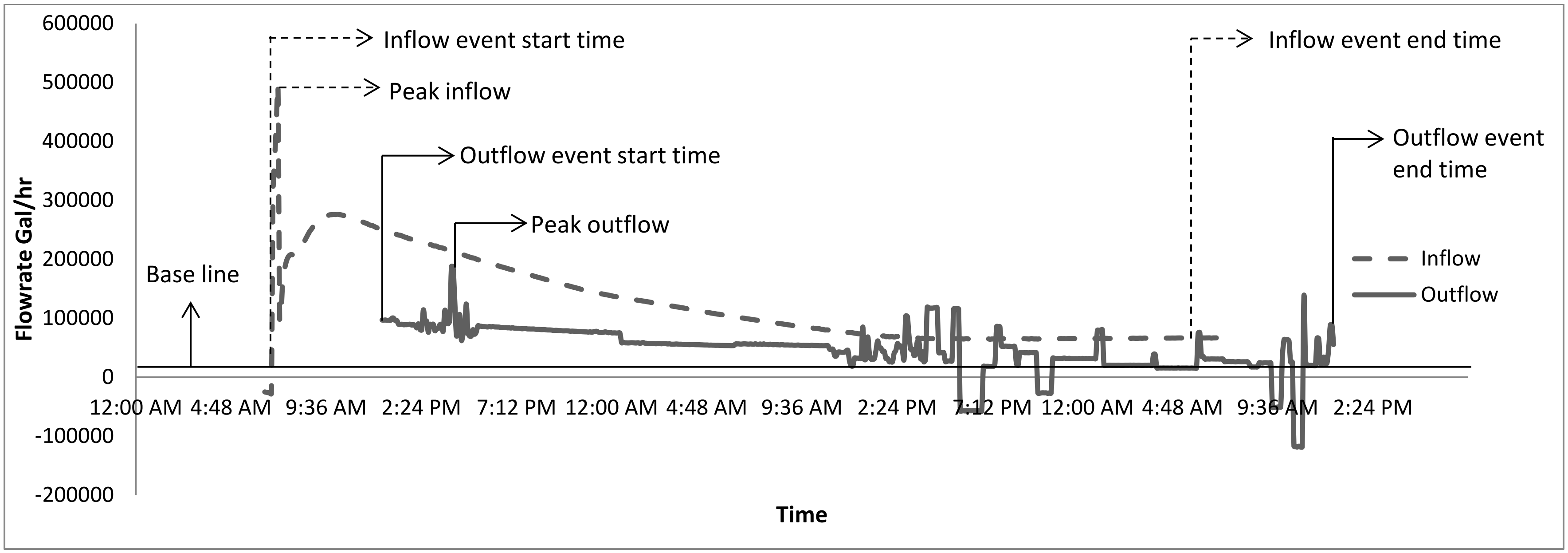


Figure B-34. Plots of inlet and outlet flow for estimated storm event on 02/25/2012 at McAuliffe RDF, McAllen, TX.

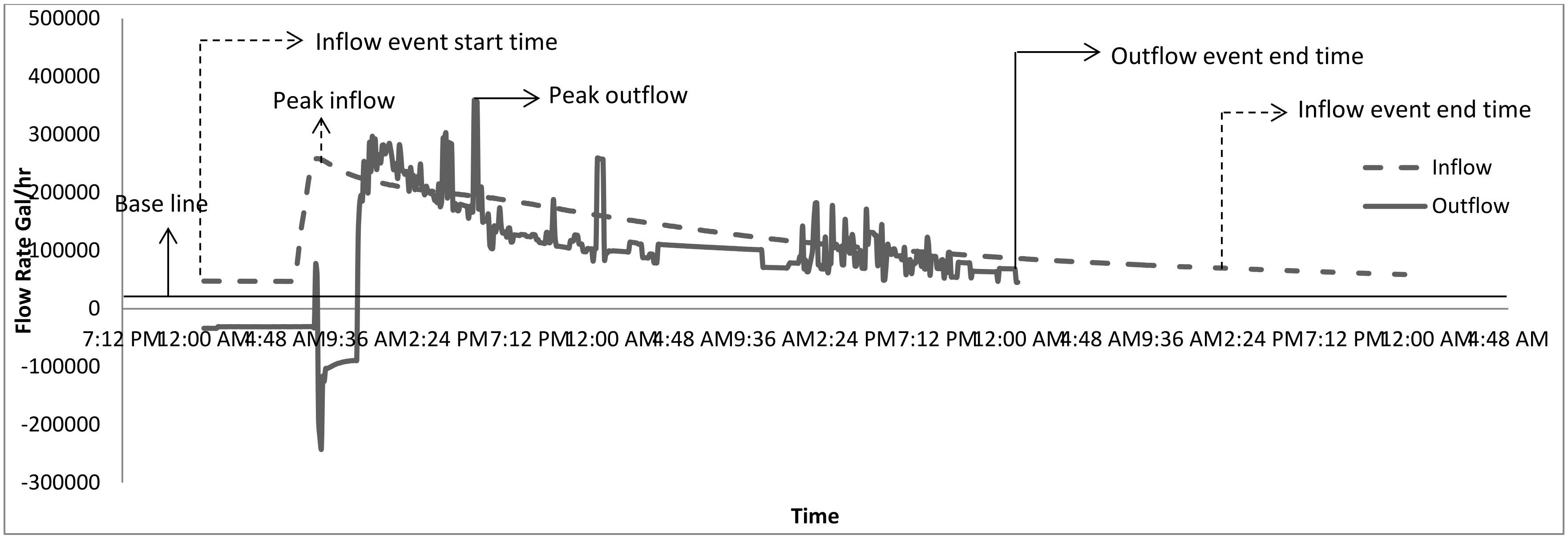


Figure B-35. Plots of inlet and outlet flow for estimated storm event on 09/14/2012 at McAuliffe RDF, McAllen, TX.

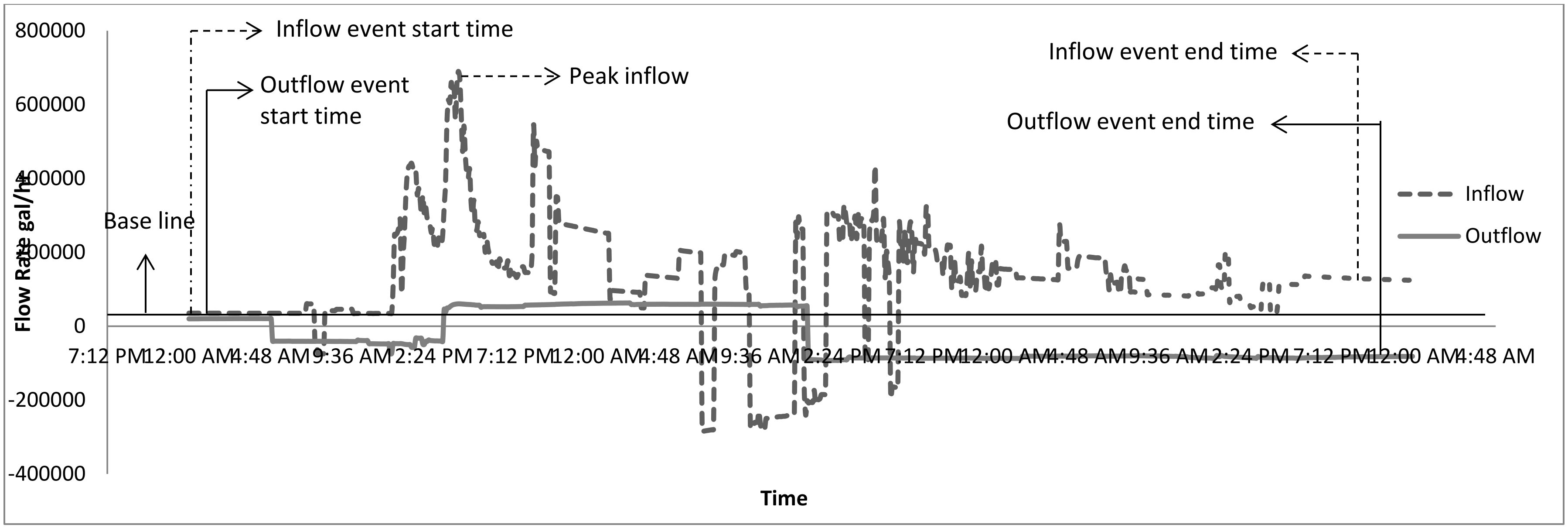


Figure B-36. Plots of inlet and outlet flow for estimated storm event on 09/27/2012 at McAuliffe RDF, McAllen, TX.

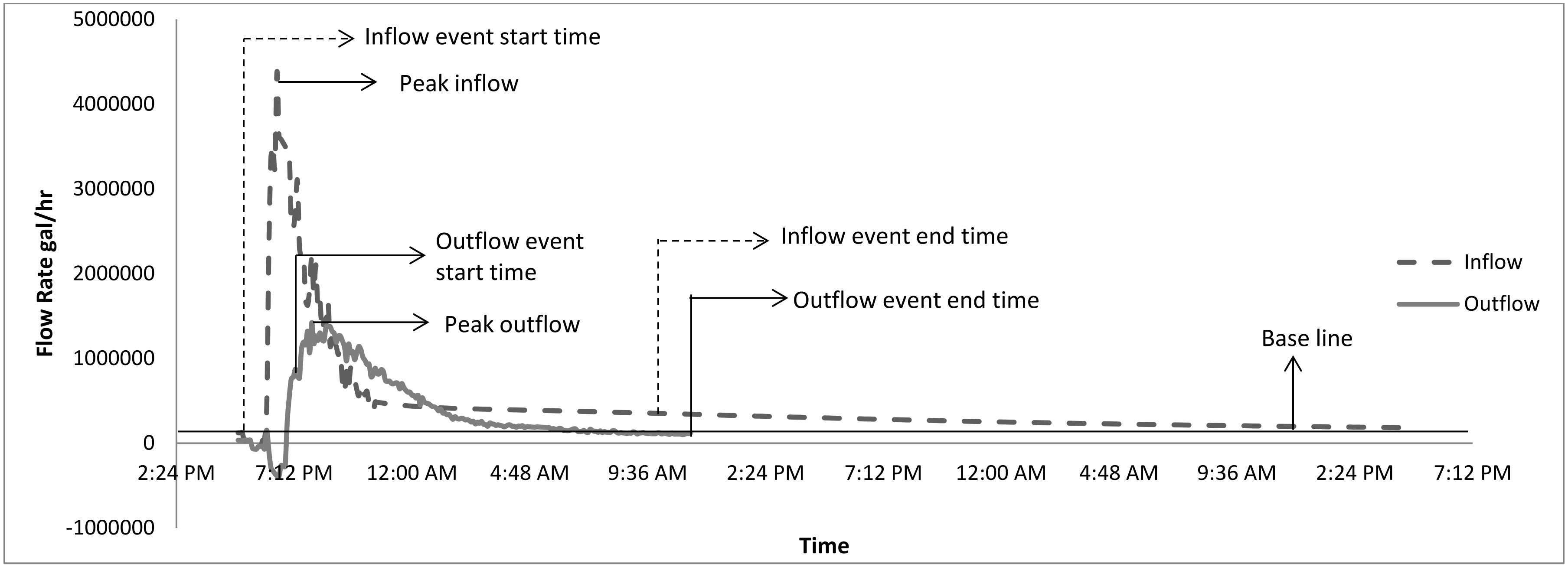


Figure B-37. Plots of inlet and outlet flow for estimated storm event on 10/18/2012 at McAuliffe RDF, McAllen, TX.