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Robert P. Astorino
County Executive

Office of the County Executive

Thomas J. Lauro, P.E.
Commissioner

Department of Environmental Facilities

Ms. Shohreh Karimipour, P.E.
NYS Department of Environmental Conservation
Region III Office
100 Hillside Avenue
Suite 1 W
White Plains, NY 10603-2860

June 13, 2013

RE: Submission of the Long Island Sound Sanitary Sewer Districts Flow Monitoring Program Report, Revised , June 2013, under the Order on Consent, dated December 30, 2008 (Case No. 3-20080730-65)

Dear Ms. Karimipour:

Enclosed please find one copy of the Long Island Sound Sanitary Sewer Districts Flow Monitoring Program Report, Revised June 2013, prepared as part of the Long Island Sound Wastewater Treatment Plant Improvement Program for the County of Westchester in accordance with Appendix "A" Schedule of Compliance", action item "18" of the above referenced Order on Consent. Submission of this revised final Report fulfills the County's obligation to submit a "flow reduction strategy" under the Order on Consent.

Should you require any additional information, please do not hesitate to contact me.

Very truly yours,

Thomas J. Lauro, P.E.
Commissioner

TJL/ll, Encl.

cc: WO/Encl
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Department of Public Works and Transportation
Department of Environmental Facilities

Westchestergov.com

Long Island Sound

Sanitary Sewer Districts

Flow Monitoring Program Report

September 2012

Revised June 2013

Savin Engineers, P.C.

REPORT

WESTCHESTER COUNTY, NEW YORK
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DEPARTMENT OF ENVIRONMENTAL FACILITIES

LONG ISLAND SOUND
SANITARY SEWER DISTRICTS
FLOW MONITORING PROGRAM REPORT

SEPTEMBER 2012
REVISED JUNE 2013

SAVIN ENGINEERS, P.C.

WESTCHESTER COUNTY, NEW YORK
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DEPARTMENT OF ENVIRONMENTAL FACILITIES

LONG ISLAND SOUND
SANITARY SEWER DISTRICTS
FLOW MONITORING PROGRAM REPORT

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1.0 EXECUTIVE SUMMARY

1.1 Background

Westchester County owns and operates four (4) wastewater treatment plants (WWTPs) that discharge to Long Island Sound (LIS). These four LIS WWTPs (Blind Brook, Mamaroneck, Port Chester and New Rochelle) operate in accordance with State Pollutant Discharge Elimination System (SPDES) Permits that are issued by the New York State Department of Environmental Conservation (NYSDEC).

In an effort to enhance the water quality of Long Island Sound, NYSDEC modified the LIS WWTP SPDES Permits to include new limits on nitrogen and other pollutants. Westchester County and NYSDEC negotiated an Order-On-Consent which was executed in December 2004. A revised Consent Order was executed in December 2008. The Order-On-Consent identified timelines and deliverables in order for Westchester County to meet the revised permit requirements.

The revised Order required work at two WWTPs (Mamaroneck and New Rochelle) to remove nitrogen, with a total project cost of $385M. In addition, the revised 2008 Order-on-Consent required the preparation of a Flow Reduction Strategy to address the reduction of Inflow/Infiltration (I/I) within the collection systems of the contributory municipalities.

This Flow Monitoring Program Report has been prepared to comply with this requirement of the Consent Order.

I/I in the Westchester County Sewer Districts is a significant problem, contributing up to 50% of the flow to the WWTPs. It is to be expected that the aging sewer systems will continue to deteriorate and I/I will continue to increase.

The nitrogen treatment facilities were designed on the basis of an aggregate design flow of 54.8 MGD at all 4 LIS WWTPs. These design flows were based on existing flow levels, future developments within each sewer district, plus a 10% contingency. These design flows do not take into consideration any increase in flow due to changes in I/I within each sewer district. The assumption is that any deterioration in the system will be offset by any I/I removed by rehabilitation. Accordingly, the development of long term strategies to mitigate any additional I/I is necessary.

Westchester County began its Capacity, Management, Operation and Maintenance (CMOM) program of its trunk sewer system in 2004. The objective of the program is to inspect, evaluate and rehabilitate all County trunk sewers and manholes on a rotating basis. As of September 2012, the County has conducted CCTV inspection of 558,000 linear feet of trunk sewer and inspected over 2,100 manholes. Most of the trunk sewers and manholes in the four LIS sewer districts have been inspected. The County has already completed rehabilitation in sections of the Saw Mill Trunk Sewer and the Westlake Trunk Sewer, both of which are located in the Town of New Castle. Rehabilitation design is ongoing for other sections of trunk sewer and manholes in the LIS districts and other sewer districts in the County. The inspection and evaluation program is also ongoing.

However, a majority of the collection system is not owned by Westchester County, but owned by the local municipalities. There is currently no means to identify which municipalities in each Sewer District are responsible for I/I and to what extent.

The Westchester County Environmental Facilities Sewer Act defines excessive I/I as follows:

> Section 824.72.2 “Excessive Infiltration and Inflow means the quantity of flow entering the County sewer system which is greater than 150 gallons per capita per day”.

Therefore, the recommended strategy was to conduct a flow monitoring program that would allow for quantification of per capita flows on a municipality-by-municipality basis to identify those municipalities with excessive I/I.

I/I has significant impacts on both the sewage collection system and the WWTPs including:

- decreased conveyance capacity in the piping system resulting in less capacity available for new development
- backups in and overflows from the sewer system
- increased pumping costs
- increased capital costs and operation and maintenance costs (O&M) at the WWTPs
- decreased treatment capability at the WWTPs, particularly at the new nitrogen facilities, possibly requiring additional capital expenditures.

More detailed background information can be found in ***1.0 Background***, starting on page 1-1 of the main report**.**

2.0 Program Description

The Long Island Sound Flow Monitoring Program included 82 flow meters deployed at strategic locations to isolate and measure flow rate from each of the 11 municipalities that discharge sewage into the four Long Island Sound Sanitary Sewer Districts (Blind Brook, Mamaroneck, New Rochelle, and Port Chester). A small area of North Castle discharges a negligible quantity of sewage to the Blind Brook District. The flow from North Castle is below the limits of the flow meters to obtain accurate measurements.

Twelve rain gages were also installed throughout the study area to measure rainfall. Flow and rainfall data were collected continuously over a two-year period from April 2009 through March 2011. The flow meters measured depth and velocity of the sewage at 15-minute intervals throughout the monitoring period. This data was used to calculate daily average flow rate for each municipality for each day during the 2-year monitoring period.

Census data from 2010 was used to estimate population in each of the 11 municipalities that discharge into the Long Island Sound sewer districts. Per capita flow rates (gallons of sewage per person per day, gpcd) were calculated based on the flow rates and population estimates. An allowance for net influx of daytime commuters was incorporated into the per capita flow rates in accordance with provisions in the Environmental Facilities Sewer Act. North Castle was not included in the analysis because it discharges a negligible quantity of sewage into the Blind Brook Sewer District.

Refer to ***2.0 Program Description*** for more detailed information**.**

3.0 Study Area

The study area is comprised of the following four Westchester County sanitary sewer districts:

- Blind Brook Sanitary Sewer District,
- Mamaroneck Sanitary Sewer District,
- New Rochelle Sanitary Sewer District, and
- Port Chester Sanitary Sewer District.

Wastewater from these sewer districts flows through collector sewers owned and maintained by the local municipalities. The collector sewers discharge into the trunk sewers which are owned and maintained by Westchester County.

The following 12 municipalities are entirely or partially within the four sanitary sewer districts

Municipality	
Harrison	Pelham Manor
Larchmont	Port Chester
Mamaroneck (Village)	Rye
Mamaroneck (Town)	Rye Brook
New Rochelle	Scarsdale
North Castle	White Plains

Refer to ***3.0 – Study Area*** for additional information

4.0 Monitoring Locations

The borders of the municipalities and sewer districts were delineated on maps of the sewer districts provided by Westchester County. All sewers that crossed a municipal or sewer district boundary were also delineated. Key manholes were then identified where flow meters would be placed. The key manhole is the manhole located just downstream of the municipal boundary, through which the upstream sewage flows. The purpose of identifying these key manholes was to isolate flow from each municipality. The preferred key manhole was located just downstream of the municipal border. Ultimately, flow meters were installed in 82 key manholes throughout the 11 municipalities of the four LIS sewer districts.

Rain gages were installed throughout the LIS sewer districts in order to differentiate wet-weather flows from dry-weather flows. The rain gages were installed on flat rooftops of such places as municipal buildings, police stations, wastewater treatment plants, etc, in order to provide an open area, while also decreasing the potential for vandalism.

For additional information refer to ***4.0 Monitoring Locations.***

5.0 Flow Monitoring System

It was determined that the Teledyne ISCO (ISCO) combined flow monitoring and telemetry system would be well suited for this monitoring program. The system provided a combination of accuracy, dependability, analysis tools, diagnostic tools, and telemetry.

The Flow Module measures flow depth with a pressure transducer, and uses continuous wave Doppler technology to measure mean velocity. Both flow depth and velocity were recorded in fifteen-minute increments for the entire duration of the flow monitoring program.

The ISCO rain gage was used to record rainfall. It is a tipping bucket rain gage that records rainfall at increments of 0.01 inches. Rainfall was recorded at five-minute increments at each of the twelve rain gage locations throughout the four LIS sewer districts for the duration of the flow monitoring program.

The use of wireless telemetry allowed for a daily check of all 82 flow meter and 12 rain gage sites from a remote location in minutes. The typical telemetry system consisted of a cellular modem module and an antenna which was either buried in the pavement adjacent to a manhole for street applications or installed nearby in the woods.

The modem module is factory-configured to deliver flow meter data to a remote server database. For the purposes of this monitoring program it was determined that a 24 hour data transmission interval would be used. This means that data was recorded at fifteen-minute intervals by the meter, 24 hours a day, seven days a week. The cell modem subsequently transmitted the data from the site directly to the dedicated server once every 24 hours.

For more detailed information, refer to ***5.0 Flow Monitoring System.***

6.0 Data QA/QC

Extensive steps were taken to ensure that the data collected was both accurate and reliable. Prior to meter installation, both office and field verifications of the proposed flow monitoring locations and equipment were conducted. These QA/QC checks included the following: municipal boundary and meter locations check; algorithm check; and comparison of official municipal boundaries against boundaries shown on the sewer system maps.

Once the flow meters were installed, field crews continued QA/QC efforts by conducting the field verification checks including routine site maintenance and telemetry spot checks.

Crews confirmed in the field that each of the 82 meter sites were installed in the correct manholes, in the correct lines.

A comparison was conducted of the County plant meters against the flow meters installed in the sewer system. In order to accomplish this task, Westchester County calibrated its meters at each of the four LIS Wastewater Treatment Plants. The County plant meters were calibrated between May and August 2009. Once the calibrations were completed, the County provided the monthly flow data for each of the four LIS Plants. The daily average flow as measured by the County plant meters was in agreement with daily average plant flows calculated from the meters in the sewer system.

An additional check of the sewer system meters was undertaken by temporarily installing supplemental meters at each of the nine meter locations near the wastewater treatment plants (two meters at Mamaroneck, three each at New Rochelle and Blind Brook, and one meter at Port Chester) in order to further confirm meter accuracy. These supplemental meters were installed for a two month period between February 22, 2010 and April 20, 2010, in the same manholes as the original sewer system meters. All meters were the same make and model. During this two month period, the original meters continued to record data, which was then compared to the supplemental meter data collected during the same time period. The data from all nine supplemental meters tracked well with the original meters and was well within the level of accuracy of the metering equipment.

In addition to these nine supplemental meters, supplemental meters were also installed at an additional 19 locations, for a total of 28 of the 82 (34%) metering sites. Each of these supplemental meters also tracked well with their corresponding original locations. The data from each set of meters was well within the level of accuracy of the meters.

Additional information on QA/QC is detailed in ***6.0 Data QA/QC.***

7.0 Population Estimates

In order to determine the daily average per capita flow rate a population estimate for each municipality needed to be developed.

For populations for municipalities entirely within the LIS Sewer Districts, census data from 2010 was used, as provided by the Westchester County Department of Planning.

For populations for municipalities that also discharge to the Yonkers Joint Sewer District, population estimates were based on block and lot census tracts from the 2010 census and on individual house counts.

An allowance of 30 gallons per commuter in each municipality for each weekday was incorporated into all per capita flow rate calculations. This allowance was not incorporated into the weekend flow rate calculations.

Additional information is included in ***7.0 Population Estimates.***

8.0 Municipality Flow Rates

The main objective of this flow monitoring program was to determine which, if any, municipalities exceed the 150 gallons per capita per day flow rate limit. Daily average flow rates were calculated based on the combined 15-minute flow metering data for each municipality. The final per capita flow rates were then calculated by subtracting the commuter allowance for each municipality from the daily average flow rate (weekdays only), then dividing by the population estimate for that municipality.

Section 824.72.2 of the Westchester County Environmental Facilities Sewer Act states that "Excessive infiltration and inflow means the quantity of flow entering the County sewer system which is greater than 150 gallons per capita per day".

Figure ES-1 shows the results of the Flow Metering Program. The figure shows the number of days and percent of time each municipality exceeded the 150 gpcd. The monitoring program lasted for 730 consecutive days. All municipalities exceeded the 150 gpcd, ranging from a low of 12% of the days during the monitoring program to a high of 61% of the days during the monitoring program.

More information is included in ***8.0 Municipality Flow Rates.***

9.0 Flow Reduction Strategies

There are several methods that have been used successfully to reduce extraneous I/I into public sewer systems. These methods include identifying and reducing I/I from the public sewers such as defective manholes and defective sewers in the public domain. Effective I/I reduction programs also include identifying and reducing I/I from private sources such as basement sump pumps and roof leaders that discharge into public sewers, and rehabilitation of defective private service laterals. The various methods that can be used to identify and reduce I/I from public and private sources are described in more detail in ***9.0 Flow Reduction Strategies***.

10.0 Recommendations

Based on the findings of the flow monitoring program, all 11 municipalities that discharge wastewater into the Long Island Sound sewer districts, to varying degrees, exceed the 150 gpcd allowance in the Westchester County Environmental Facilities Sewer Act.

The overall flow reduction strategy would include the following sequential steps for each municipality as shown in the attached Proposed Schedule, Figure ES-2:

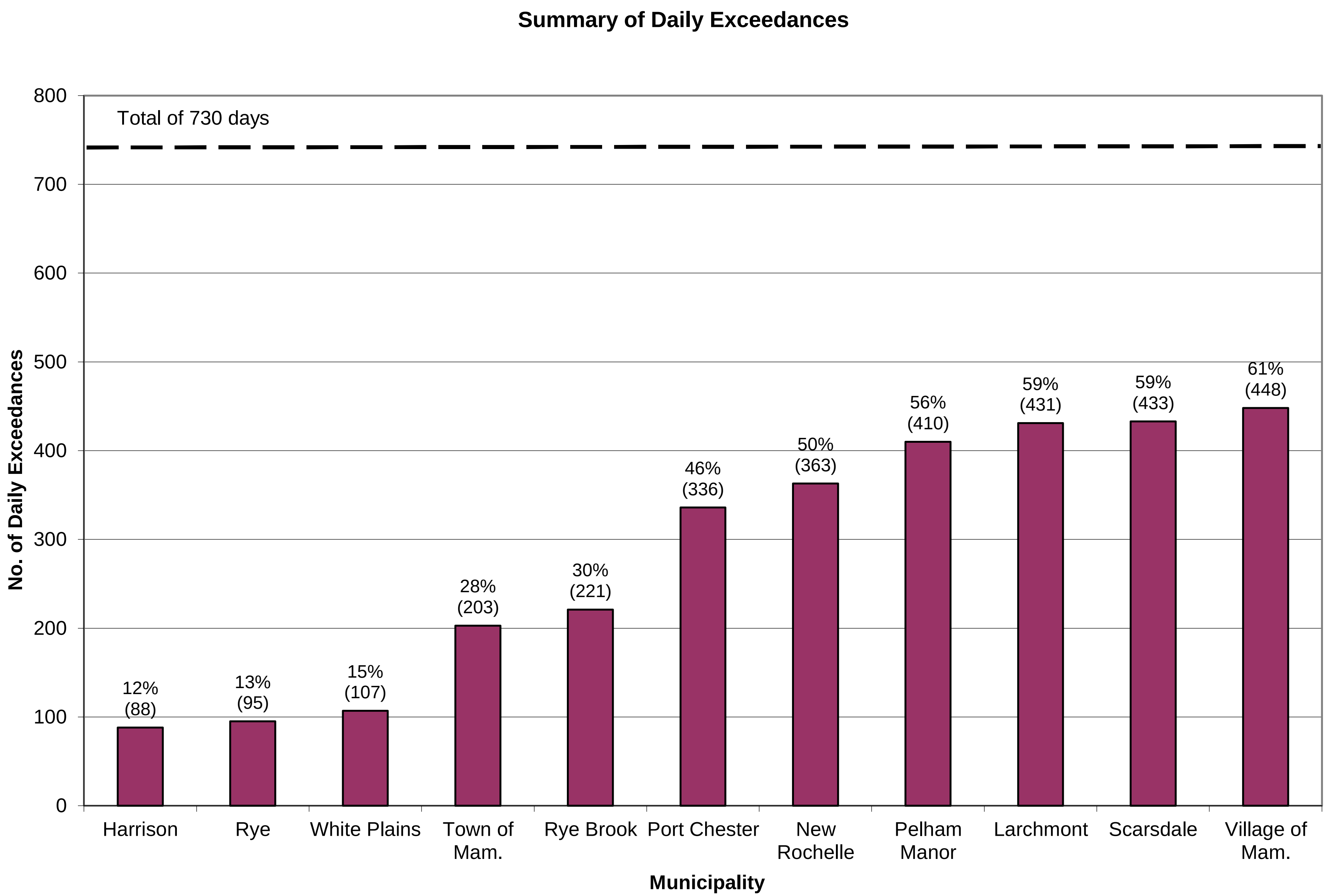
- ***Municipality Negotiations:*** It is recommended that Westchester County enter into negotiations with the 11 municipalities to get concurrence from each municipality to develop a program to address the excessive I/I in their sewer systems.

- ***Evaluation Program Development:*** Each municipality will develop municipality specific scope of the Evaluation Program which will entail flow metering, flow isolation, smoke testing, CCTV inspection, lateral inspection, house to house inspections and analysis of field data collected to identify a remedial program to reduce infiltration/inflow within each municipality. The Evaluation Program developed by each municipality should be submitted to Westchester County and NYSDEC for review.

- ***Evaluation Program Implementation:*** Each municipality will implement the Evaluation Program. Prepare a report for submittal to Westchester County and NYSDEC which identifies the necessary repairs, develop a construction cost estimate for the Program and outline the design and construction schedule for implementation.

Following the submittal of the Evaluation Program Report by the 11 municipalities, which will outline the extent, cost and schedule of the rehabilitation programs, Westchester County and NYSDEC will meet to review and discuss the reports and either accept the programs and associated schedules, or request modifications and/or clarifications. Final acceptance of all 11 programs and the associated schedules will be conveyed to the municipalities by Westchester County and NYSDEC by August 1, 2017.

Figure ES-1



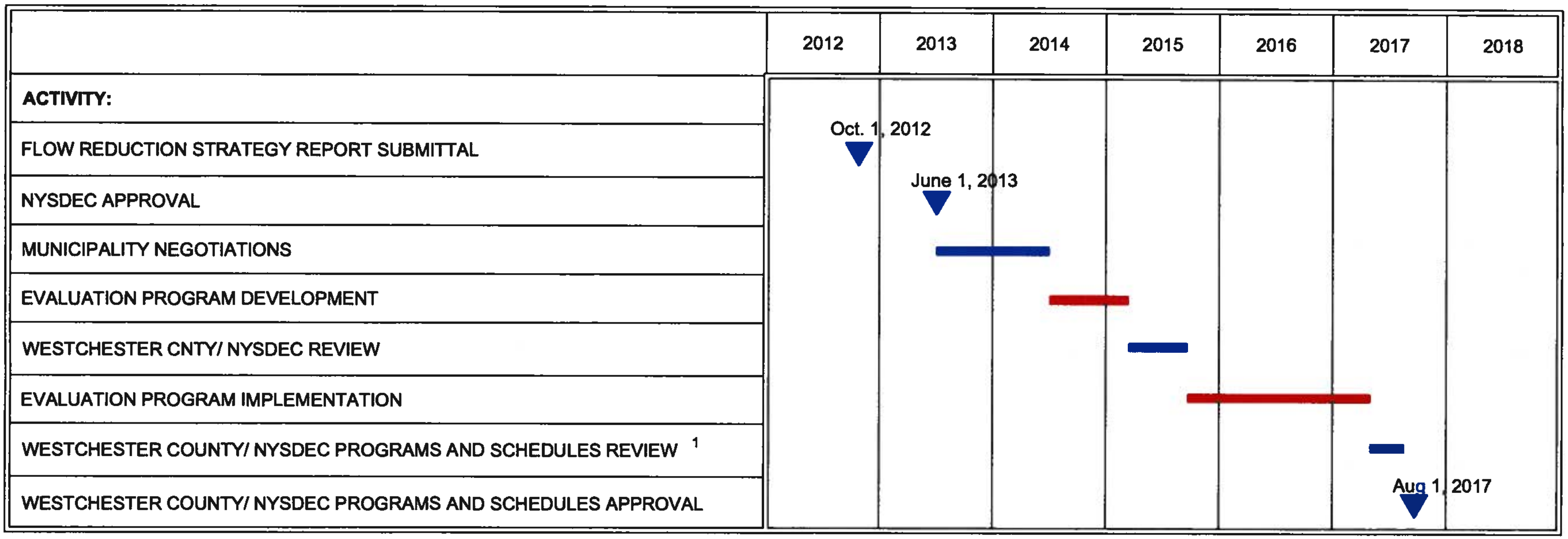
Savin Engineers, P.C.

WESTCHESTER COUNTY
DEPT. OF PUBLIC WORKS & TRANSPORTATION
DEPT. OF ENVIRONMENTAL FACILITIES

FIGURE ES-2

LONG ISLAND SOUND SEWER DISTRICTS
FLOW REDUCTION STRATEGY

PROPOSED SCHEDULE



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KEY

- WESTCHESTER COUNTY / NYSDEC ACTION (blue)
- MUNICIPALITY ACTION (red)

REV. 4 5/14/2013

1. WESTCHESTER COUNTY AND NYSDEC WILL REVIEW AND DISCUSS ALL THE PROPOSED PROGRAMS AND IMPLEMENTATION SCHEDULES WHICH ARE SUBMITTED BY THE MUNICIPALITIES AND APPROVE EACH ONE, AS MODIFIED BY THE REVIEW PROCESS, BY AUGUST 1, 2017.

Savin Engineers, P.C.

WESTCHESTER COUNTY, NEW YORK
DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION
DEPARTMENT OF ENVIRONMENTAL FACILITIES

LONG ISLAND SOUND
SANITARY SEWER DISTRICTS
FLOW MONITORING PROGRAM REPORT

1.0 BACKGROUND

1.1 Introduction

Westchester County owns and operates four (4) wastewater treatment plants (WWTPs) that discharge to Long Island Sound (LIS). These four LIS WWTPs (Blind Brook, Mamaroneck, Port Chester and New Rochelle) operate in accordance with State Pollutant Discharge Elimination System (SPDES) Permits that are issued by the New York State Department of Environmental Conservation (NYSDEC).

In an effort to enhance the water quality of Long Island Sound, NYSDEC modified the LIS WWTP SPDES Permits to include new limits on nitrogen and other pollutants. Westchester County and NYSDEC negotiated an Order-On-Consent which was executed in December 2004. The Order-On-Consent identified timelines and deliverables in order for Westchester County to meet the revised permit requirements. Among the deliverables was the submittal of an Engineering Plan by December 24, 2006. That Engineering Plan identified recommended nitrogen removal projects at all four WWTPs, with total project costs of $505M.

Because of the costs involved, Westchester County re-negotiated the terms of the Consent Order. On December 30, 2008 a revised Consent Order was executed. The revised Order required work at two WWTPs (Mamaroneck and New Rochelle) to remove nitrogen, with a total project cost of $385M. In addition, the revised 2008 Order-on-Consent also had the following two requirements:

- Development of a Second Engineering Plan to address steps to be taken should the nitrogen removal work at New Rochelle and Mamaroneck not achieve the aggregate 12 month rolling average Total Nitrogen (TN) discharge limit stipulated in the 2008

Consent Order. This Second Engineering Plan was submitted to NYSDEC on December 31, 2011 and was approved by NYSDEC on March 12, 2012.

- Preparation of a Flow Reduction Strategy to address the reduction of Inflow/Infiltration (I/I) within the collection systems of the contributory municipalities.

This Flow Monitoring Program Report has been prepared to comply with the second requirement of the Consent Order.

1.2 Inflow and Infiltration (I/I)

Inflow – extraneous surface water entering the sewer system as a result of rainstorms. Examples of inflow sources are stormwater sewer system cross connections, leaking manhole covers, yard drain connections and roof leader connections.

Infiltration – extraneous groundwater entering the sewer system, usually a result of an aging, deteriorating collection system. Examples of infiltration sources are cracked or broken manhole walls, cracked or broken sewer pipes, offset joints, cracked or broken laterals and basement sump pumps.

I/I in the Westchester County Sewer Districts is a significant problem, contributing up to 50% of the flow to the WWTPs. It is to be expected that the aging sewer systems will continue to deteriorate and I/I will continue to increase.

The nitrogen treatment facilities were designed on the basis of an aggregate design flow of 54.8 MGD at all 4 LIS WWTPs. These design flows were based on existing flow levels, future developments within each sewer district plus a 10% contingency. These design flows do not take into consideration any increase in flow due to changes in I/I within each sewer district. The assumption is that any deterioration in the system will be offset by any I/I removed by rehabilitation. Accordingly, the development of long term strategies to mitigate any additional I/I is necessary.

Westchester County has an existing, ongoing evaluation and rehabilitation program of its trunk sewer collection system throughout the County. However, a majority of the collection system is not owned by Westchester County, but owned by the local municipalities. The remaining sources of I/I are attributable to either: (1) that portion of the collection system owned by the local municipalities or (2) conditions on private property, including deteriorated lateral connections and/or illegal connections, which the local municipalities are responsible for correcting. There is currently no means to identify which municipalities in each Sewer District are responsible for I/I and to what extent.

The Westchester County Department of Environmental Facilities Sewer Ordinance defines excessive I/I as follows:

> Section 824.72.2 "Excessive Infiltration and Inflow means the quantity of flow entering the County sewer system which is greater than 150 gallons per capita per day".

Therefore, the recommended strategy in the Engineering Plan was to conduct a flow monitoring program that would allow for quantification of per capita flows on a municipality-by-municipality basis.

1.3 I/I Impacts

Why is I/I in the public sewer system an issue of concern and why is it important that it not be allowed to increase through further deterioration of the sewer system?

Generally, when I/I enters the collection system, it is conveyed to the WWTP where it is treated with the other sewage, meaning that it impacts both the collection system and the WWTP.

1.3.1 Collection System Impacts

The sanitary sewer collection systems in the Westchester County Sewer Districts, which are owned by the municipalities, are generally old and, other than the 2002 County rehabilitation program, have not undergone any extensive repairs. I/I in the public sewers is not the only problem. There is a significant I/I contribution from leaking, privately owned laterals that connect private dwellings and businesses to the collection system, and from basement sump pumps.

Significant I/I problem within the collection system leads to the following:

- Conveyance capacity for sewage in the piping system is decreased as a result of I/I. This directly impacts the available capacity for new development.

- When the capacity of the sewers is exceeded, backups into private homes occur with basement flooding and the attendant property damage, health impacts and violation of NYSDEC and Westchester County Department of Health (WCDOH) regulations.

- Overflows from the sewer system to the receiving waters occur.

    - During significant rain events, sewage also overflows from manholes and flows down streets, eventually reaching receiving waters. These overflows are raw sewage overflows and have significant public health impacts on both property and receiving waters and are a violation of NYSDEC and WCDOH regulations. The worse the I/I problem, the more frequent the overflows.

    - Exfiltration of wastewater through defects in the sanitary sewer can occur, which could lead to contamination of groundwater and receiving waters.

    - In New Rochelle, these overflows occur at the Overflow Retention Facilities (ORFs) and are known as Sanitary Sewer Overflows (SSOs). Each event would have an associated Operation and Maintenance cost.

- Most sewer districts have numerous satellite pumping stations which pump the sewage to the WWTPs. The extraneous I/I, up to the pumping capacity of the station, is also pumped to the WWTP. There is a significant energy cost associated with such additional pumping. (When the capacity of a pumping station is exceeded, backups and overflows, as outlined above, can occur).

1.3.2 Wastewater Treatment Plant Impacts

Generally, when the I/I reaches the WWTP, it receives the same treatment as sewage entering the plant. The impacts of I/I on the WWTP are as follows:

- Facilities Cost: (Capital) – A significant portion of capital cost of any future expansion can be attributed to providing treatment for future I/I flows.

- Treatment Cost (O&M) – The annual O&M cost at the WWTPs is significantly impacted by the need to treat the I/I.

- Energy Use – Energy consumption at the plants is impacted in direct proportion to the percent I/I in the flow. Since approximately 50% of flow at the 4 LIS WWTPs is I/I, accordingly, half the energy cost is to treat I/I.

- Permitted Flow Exceedence – Each WWTP has a SPDES Permit which specifies a flow limit. During wet weather periods when I/I is high, the flow limit can be exceeded, possibly resulting in a SPDES Permit violation.

- Percent Removal Violations – The SPDES Permit limit for CBOD and TSS is 25 and 30 mg/l respectively, and 85% removal for both. Excessive I/I dilutes the wastewater and makes it difficult to achieve 85% removal, resulting in SPDES Permit violations.

- Nitrogen Removal – The new Nitrogen Removal Facilities are being designed to treat the maximum monthly flow. No allowance is being included to account for increase in I/I quantities. Should the collection system continue to deteriorate and I/I increase, the facilities will be hydraulically overloaded, leading to incomplete treatment and associated SPDES Permit violations.

- Treatment Capacity – Each gallon of I/I robs the WWTP capacity to treat sanitary sewage. County WWTPs are severely site constrained. There is no additional space available to expand the plant to accommodate more I/I.

- Fines – Fines for violations of SPDES Permit limits can be as high as $37,500 per day per WWTP.

1.4 Flow Monitoring

The first step to identifying the municipalities with excessive I/I is to establish a Flow Monitoring Program which will isolate and quantify the flow from each municipality within each Sewer District. Utilizing population data, the average per capita flow for each day can then be determined.

The subsequent sections of this report detail the flow monitoring program and the results obtained.

2.0 PROGRAM DESCRIPTION

The objective of the flow monitoring program was to isolate and quantify wastewater flow from each municipality discharging into the four LIS sewer districts and to determine which municipalities were contributing excessive I/I. The daily flow rates, on a per capita basis, were then compared to the limit in the Westchester County Environmental Facilities Sewer Act.

Eighty two flow meters were deployed at strategic locations in the sewer system to isolate flow from each of the 11 municipalities. The monitoring was conducted continuously from April 2009 through March 2011. The program was based on a two-year monitoring period to include a wide range of weather conditions such as prolonged wet periods, intense rainfalls, prolonged dry periods, snow melt, high groundwater and low groundwater conditions. The flow meters collected measurements of both depth and velocity of the sewage every 15 minutes throughout the monitoring period. Daily average flow rates were calculated from the 15-minute data.

Twelve rain gages were installed in the study area to determine the impact of rainfall on flow rates. The rain gages were placed throughout the large study area to provide spatial coverage and to capture differences in rainfall volume and intensity in the different areas. The rain gages were the tipping bucket type and measured rainfall every five minutes in increments of 0.01 inches.

Census data from 2010 was used to estimate the population of each municipality within each LIS sewer district. Lot and block census data was used to estimate the population of each municipality that discharged into one of the Yonkers Joint Sewer Districts. The net influx of daily commuters was provided by the County Planning Department. An allowance was provided to account for the commuters when the per capita flow rates were calculated.

The calculated flow rates were used in conjunction with the population estimates and the commuter allowance to determine a per capita flow rate from each municipality. Daily average per capita flow rates were calculated for each day during the two-year period. The per capita flow rates were then used to determine which municipalities were discharging excessive I/I, defined as flow greater than 150 gallons per capita per day in the Westchester County Environmental Facilities Sewer Act.

3.0 STUDY AREA

3.1 Sewer Districts

The study area, shown in Figure 3-1, is comprised of the following four Westchester County sanitary sewer districts:

- Blind Brook Sanitary Sewer District,
- Mamaroneck Sanitary Sewer District,
- New Rochelle Sanitary Sewer District, and
- Port Chester Sanitary Sewer District.

Wastewater from these sewer districts flows through collector sewers owned and maintained by the local municipalities. The collector sewers discharge into the trunk sewers which are owned and maintained by Westchester County. The wastewater is treated at the County-owned wastewater treatment plant in each district. Treated effluent is discharged into the Long Island Sound. The effluent parameters at each wastewater treatment plant (such as biochemical oxygen demand, suspended solids, and nitrogen load) are governed by a permit issued by the New York State Department of Environmental Conservation. The permits also include requirements for flow rate at each treatment plant.

3.2 Municipalities in the Study Area

Figure 3-1 shows the 12 municipalities that are entirely or partially within the four sanitary sewers districts. A small portion of the Town of North Castle is in the Blind Brook Sewer District. That portion of the Town of North Castle discharges a negligible quantity of sewage into the Blind Brook District. The other 11 municipalities discharge into one or more of the four LIS Districts. Portions of Pelham Manor, Scarsdale, and White Plains also discharge sewage into the Yonkers Joint Sewer Districts. Table 3-1 lists the municipalities and the sewer districts into which they discharge.

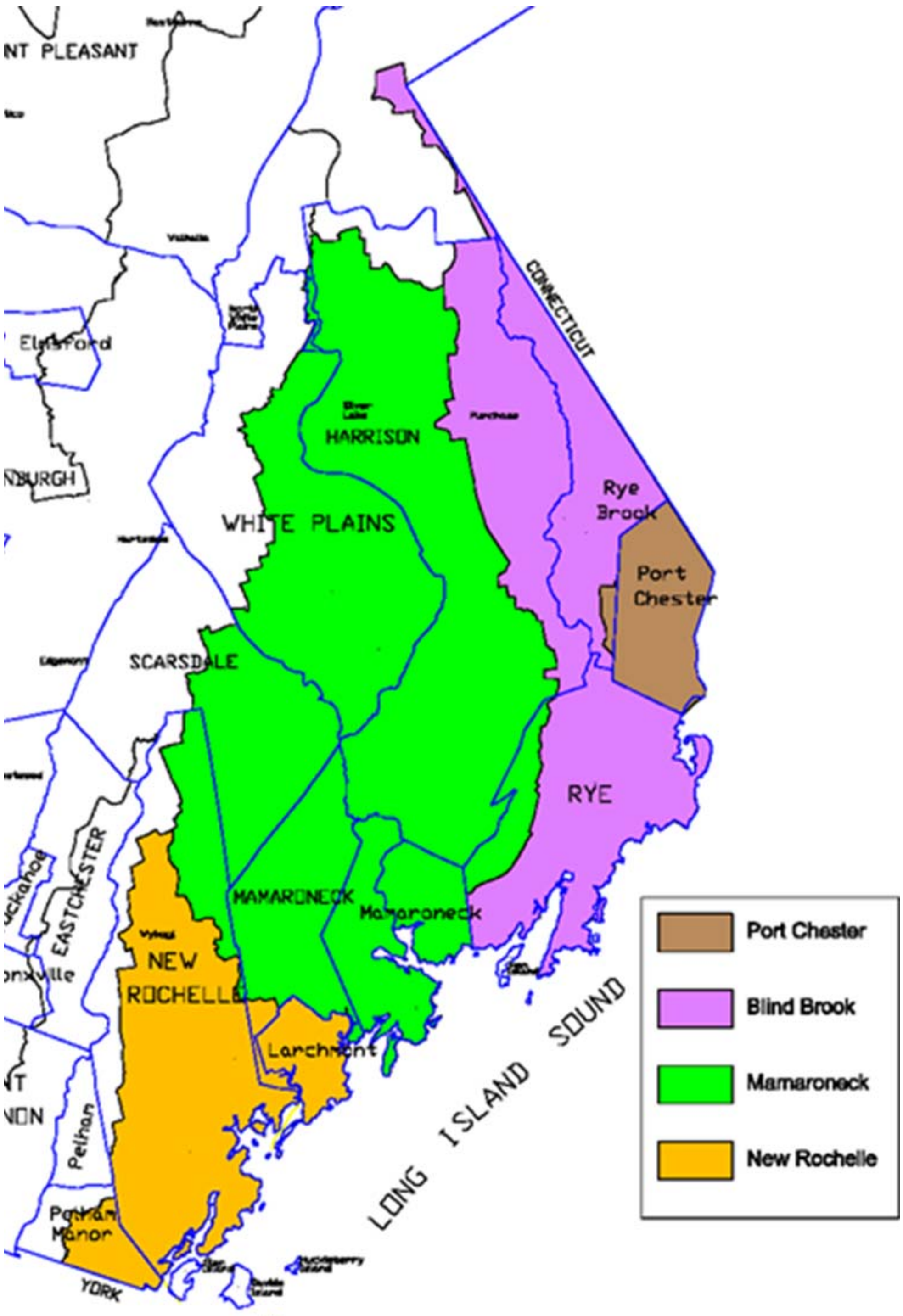
TABLE 3-1

MUNICIPALITIES IN THE LONG ISLAND SOUND SANITARY SEWER DISTRICTS

Municipality	Discharge Location (Sewer District)
Harrison	Blind Brook, Mamaroneck
Larchmont	New Rochelle
Mamaroneck (Village)	Blind Brook, Mamaroneck
Mamaroneck (Town)	Mamaroneck, New Rochelle
New Rochelle	Mamaroneck, New Rochelle
North Castle	Yonkers Joint
Pelham Manor	New Rochelle, Yonkers Joint
Port Chester	Port Chester
Rye	Blind Brook, Mamaroneck
Rye Brook	Blind Brook, Port Chester
Scarsdale	Mamaroneck, Yonkers Joint
White Plains	Mamaroneck, Yonkers Joint

Figure 3-1

Long Island Sound Sanitary Sewer Districts and Municipalities



4.0 MONITORING LOCATIONS

4.1 Flow Meter Locations

Westchester County provided four sets of photo aerial or GIS sewer maps, one for each of the four sewer districts to be monitored. The following table demonstrates the breakdown of municipalities in each of the four LIS sewer districts:

Blind Brook Sewer District	Mamaroneck Sewer District	New Rochelle Sewer District	Port Chester Sewer District
Harrison	Harrison		Port Chester
Mamaroneck (V)	Mamaroneck (V)	Pelham Manor	
Rye	Rye	Larchmont	
Rye Brook	New Rochelle	New Rochelle	Rye Brook
	Mamaroneck (T)	Mamaroneck (T)	
	Scarsdale		
	White Plains		

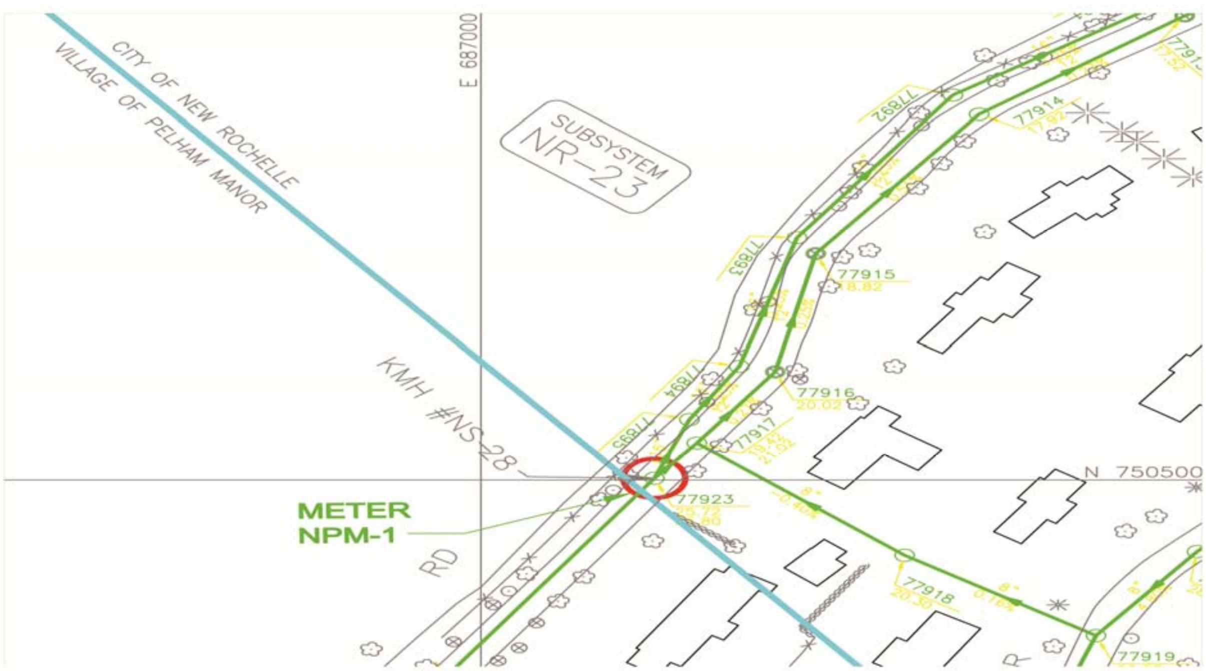
Since the maps are broken down by sewer district, there was no concern about sewers overlapping and thus, being monitored twice. For example, New Rochelle sewers in the

Mamaroneck sewer district are not shown on the New Rochelle sewer district maps and vice versa.

The borders of the municipalities and sewer districts were delineated on the maps. All sewers that crossed a municipal or sewer district boundary were also delineated. The key manholes where flow meters would be placed were identified. The key manhole is the manhole located just downstream of the municipal boundary, through which the upstream sewage flows.

The purpose of identifying these key manholes was to isolate flow from each municipality. The preferred key manhole was located just downstream of the municipal border. Field conditions at the selected sites were not always acceptable because of debris, poor hydraulic conditions, and other factors that were less suitable for flow meter installation. When this happened, alternate sites were investigated in manholes located just upstream or downstream of the original location. Care was taken not to place the meter in a manhole that included flow from another municipality. Ultimately, flow meters were installed in 82 key manholes throughout the 11 municipalities of the four LIS sewer districts. These 82 flow monitoring locations are summarized in Table 4-1.

The diagram below gives an example of one of the key manhole selections.



Here, the boundary between the Village of Pelham Manor and the City of New Rochelle can be seen. The sewer can be seen traveling in a northeasterly direction from Pelham Manor into New Rochelle. This key manhole was selected because it is the first manhole located just downstream of the sewer system boundary and would include all flow from Pelham Manor, but none from New Rochelle. If that manhole was found in the field to be buried, or inaccessible for some reason, and the location had to be relocated to a manhole farther downstream, the crew would have to be careful not to select a manhole too far downstream, as there is a line coming from the 4 o'clock direction that is entirely comprised of flow from New Rochelle.

Because flow travels from one municipality to another and ultimately discharges to the County wastewater treatment plant, flow algorithms were developed in order to isolate the upstream flows. Each algorithm added flows from meters located in the municipality that was being metered, and then subtracted flows from meters located in any upstream municipalities. An algorithm was created for each of the 11 municipalities being monitored, and then entered into the flow monitoring software program, Flowlink. Municipalities that are split between sewer districts would have a separate algorithm calculation for each sewer district. The final algorithm for those municipalities included the sum of all sewer district algorithms. The algorithms for each of the four sewer districts are shown in Tables 4-2 through 4-5.

Once all of the algorithms were incorporated into the flow monitoring software, Flowlink utilized the algorithm equations to calculate a single flow rate for each municipality. These eleven flow rates, one from each municipality, were then used to calculate the per capita flows for each municipality.

4.2 Rain Gage Locations

Rain gages were installed throughout the LIS sewer districts in order to differentiate wet-weather flows from dry-weather flows. A tipping bucket rain gage was used to record rainfall in increments of 0.01 inches, and an ISCO telemetry device was used to access rainfall data remotely. The rain gages were installed on flat rooftops of such places as municipal buildings, police stations, wastewater treatment plants, etc, in order to provide an open area, while also decreasing the potential for vandalism.

In order to provide maximum coverage for the 11 municipalities, 12 locations were selected for the rain gage installations as shown in the following table:

Rain Gauge No.	**Rain Gauge Location**	**Nearby Municipalities**
1	New Rochelle WWTP	New Rochelle, Mamaroneck (T), Larchmont
2	Blind Brook WWTP	Rye Brook
3	Mamaroneck WWTP	Mamaroneck (V), Mamaroneck (T)
4	Port Chester WWTP	Port Chester, Rye Brook
5	Saxon Woods Golf Course	Mamaroneck (V), Scarsdale
6	Village of Rye Brook	Rye Brook
7	West Harrision DPW	Harrison, White Plains
8	Harrison Police Department	Harrison, Scarsdale, Rye
9	Drake Ave Fire Department	Pelham Manor
10	New Rochelle City Hall	New Rochelle, Mamaroneck (T)
11	Quaker Ridge Fire Department	New Rochelle, Rye
12	Purchase Fire Department	Harrison

The flow monitoring software was able to superimpose rainfall data on the hydrograph for each municipality.

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Table 4-1
Flow Monitor Locations

	Meter No.	MH No.	Location	SSES Map No.	Sewer District
1	BH-1	61546	Purchase St.	D10	Blind Brook
2	BH-2	61622	Easement	D11	Blind Brook
3	BH-3	61685	Bowman Ave.	C12	Blind Brook
4	BH-4	61742	Westchester Ave.	C13	Blind Brook
5	BH-5	61832	Lincoln Ave.	C15	Blind Brook
6	BH-6	62156	Easement WC Airport	B22	Blind Brook
7	BH-7	61531	Highland Pl.	D10	Blind Brook
8	BH-8	62104	Easement	C17	Blind Brook
9	BMV-1	60352	Brevoort Lane	B2	Blind Brook
10	BNC-1	62169	WC Airport	B24	Blind Brook
11	BR-1	61139	BB WWTP	C5	Blind Brook
12	BR-2	60002	BB WWTP	C5	Blind Brook
13	BR-3	61138	BB WWTP	C5	Blind Brook
14	BRB-1	61612	Easement	D11	Blind Brook
15	BRB-2	62031	Easement	C16	Blind Brook
16	MH-1	76737	Anderson Hill Rd.	D20	Mamaroneck
17	MH-10	72240	Grove St.	F9	Mamaroneck
18	MH-12	75071	Easement off Hutch. River Pkwy.	F16	Mamaroneck
19	MH-13	75385	Westchester Ave.	F19	Mamaroneck
20	MH-14	75397	Corporate Park Dr.	F19	Mamaroneck
21	MH-15	75440	Westchester Ave.	F20	Mamaroneck
22	MH-17	75545	Easement off Westchester Ave.	F21	Mamaroneck
23	MH-18	67139	Easement off Harrison Ave.	G6	Mamaroneck
24	MH-19	72193	Park Ave.	G7	Mamaroneck
25	MH-2	76737	Westchester Ave.	D20	Mamaroneck
26	MH-20	75117	Easement off Hutch. River Pkwy.	G16	Mamaroneck
27	MH-21	75149	Easement off Westchester Ave.	G17	Mamaroneck
28	MH-22	67994	Canterbury Rd. South	H4	Mamaroneck
29	MH-23	68019	Easement off Canterbury Rd. South	H4	Mamaroneck
30	MH-24	68078	Glendale Rd.	I5	Mamaroneck
31	MH-3	76484	Underhill Place	D21	Mamaroneck
32	MH-4	76594	Silver Lake Avenue	D22	Mamaroneck
33	MH-5	68120	Easement near Apawamis Golf Course	I6	Mamaroneck
34	MH-6	75559	Westchester Ave.	E21	Mamaroneck
35	MH-8	75586	Westchester Ave.	E22	Mamaroneck
36	MH-9	65320	Ellis Pl.	F10	Mamaroneck
37	MMT-3	68881	Fenimore Rd.	D5	Mamaroneck
38	MMT-4	68540	Norman Dr. (near Amtrak)	D3	Mamaroneck
39	MMT-5	65623	Baldwin Place	D4	Mamaroneck
40	MMT-6	68863	Baldwin Place	D4	Mamaroneck
41	MMV-1	73035	Mamaroneck Ave.	E10	Mamaroneck
42	MMV-2	65660	W. Boston Post Rd.	F6	Mamaroneck
43	MMV-3	65661	W. Boston Post Rd.	F6	Mamaroneck
44	MN-1	70060	Dennis Drive	B5	Mamaroneck
45	MN-2	69458	High Ridge Road	B2	Mamaroneck
46	MN-3	69434	Poplar Road	B2	Mamaroneck
47	MN-4	69940	Locust Ridge Rd	B3	Mamaroneck
48	MN-5	71025	Wilmot Rd.	B11	Mamaroneck
49	MR-1	68361	Hornidge Rd.	G6	Mamaroneck
50	MR-10	68067	Easement	I4	Mamaroneck
51	MR-11	68077	Glendale Rd.	I5	Mamaroneck
52	MR-12	68106	Hunter Lane	I5	Mamaroneck
53	MR-2	67621	Beaver Brook	H2	Mamaroneck
54	MR-3	67638	Bradford Ave.	H2	Mamaroneck
55	MR-4	67758	Park Ave.	H2	Mamaroneck
56	MR-5	67870	Beaver Brook	H3	Mamaroneck
57	MR-7	67979	Country Rd.	H4	Mamaroneck
58	MR-8	67946	Canterbury Rd. South	H4	Mamaroneck
59	MR-9	67991	Easement off Canterbury Rd. South	H4	Mamaroneck
60	MS-1	71022	Wilmot Rd.	B10	Mamaroneck
61	MS-2	71520	Fenimore Rd.	C6	Mamaroneck
62	MS-3	71588	Griffin Ave.	C7	Mamaroneck
63	MS-4	73753	Black Birch Lane	C13	Mamaroneck
64	MS-5	73915	Carolyn Avenue	C13	Mamaroneck
65	MS-6	70877	Easement off Weaver Street	B10	Mamaroneck
66	MS-7	73734	Easement off Black Birch Lane	D13	Mamaroneck
67	MS-8	73276	Mamaroneck Ave.	E13	Mamaroneck
68	MS-9	73667	Easement off Black Birch Lane	D13	Mamaroneck
69	MW-1	73237	Mamaroneck Ave.	E13	Mamaroneck
70	NL-1	81328	Easement off Oak Ave.	F4	New Rochelle
71	NMT-1	81561	Coolidge St.	E7	New Rochelle
72	NMT-2	81110	5th Ave.	E8	New Rochelle
73	NMT-3	81244	Easement off Emerson Ave.	E5	New Rochelle
74	NN-1	81220	NRWWTP	E4	New Rochelle
75	NN-2	78718	NRWWTP	E4	New Rochelle
76	NN-3	78729	NRWWTP	E4	New Rochelle
77	NN-4	81188	Barnard Rd	E8	New Rochelle
78	NPM-1	77923	Mt. Tom Rd.	B2	New Rochelle
79	NPM-2	77810	Shore Rd.	C2	New Rochelle
80	PPC-2	90063	Fox Island Rd.	3	Port Chester
81	PRB-1	90735	West St.	8	Port Chester
82	PRB-2	91306	Neuton Ave.	14	Port Chester

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Table 4-2
Blind Brook Sewer District Algorithms

Blind Brook Sewer District Flow Monitoring Locations

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
BMV	1	60352	B2	BR2	BMV1
	TOTAL FLOW INTO BBSD TREATMENT PLANT:				**BMV1**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
BNC	1	62169	B24	BH8	BNC1
	TOTAL FLOW INTO BBSD TREATMENT PLANT:				**BNC1**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
BH	1	61546	D10	BR1	BH1
BH	2	61622	D11	BR1	BH2
BH	3	61685	C12	BRB1	BH3
BH	4	61742	C13	BRB1	BH4
BH	5	61832	C15	BRB1	BH5-(BH8+BRB2)
BH	6	62156	B22	BH8	BH6
BH	7	61531	D10	BR1	BH7
BH	8	62104	C17	BH5	BH8-BH6-BNC1
	TOTAL FLOW INTO BBSD TREATMENT PLANT:				**BH1+…+BH5+BH7-BRB2-BNC1**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
BR	1	61139	C5	BBWWTP	BR1-(BH1+BH2+BH7)-BRB1
BR	2	60002	C5	BBWWTP	BR2-BMV1
BR	3	61138	C5	BBWWTP	BR3
	TOTAL FLOW INTO BBSD TREATMENT PLANT:				**BR1+BR2+BR3-(BMV1+BH1+BH2+BH7+BRB1)**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
BRB	1	61612	D11	BR1	BRB1-(BH3+BH4+BH5)
BRB	2	62031 (out)	C16	BH5	BRB2
	TOTAL FLOW INTO BBSD TREATMENT PLANT:				**BRB1+BRB2-(BH3+BH4+BH5)**

Table 4-3
Mamaroneck Sewer District Algorithms

Mamaroneck Sewer District Flow Monitoring Locations

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MN	1	70060	B5	MMT4	MN1-MS1-MS6
MN	2	69458	B2	MMT4	MN2
MN	3	69434	B2	MMT4	MN3
MN	4	69940	B3	MMT4	MN4
MN	5	71025	B11	MS1	MN5
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MN1+…+MN5-MS1-MS6**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MMT	3	68881	D5	MMV2	MMT3
MMT	4	68540	D3	MMV2	MMT4-MN1-(MS2+MS3)-(MN2+MN3+MN4)
MMT	5	65623	D4	MMV3	MMT5
MMT	6	68863	D4	MMV3	MMT6
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MMT3+…+MMT6-MN1-(MS2+MS3)-(MN2+MN3+MN4)**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MS	1	71022	B10	MN1	MS1-MN5
MS	2	71520	C6	MMT4	MS2
MS	3	71588	C7	MMT4	MS3
MS	4	73753	C13	MW1	MS4
MS	5	73915	C13+C14	MW1	MS5
MS	6	70877	B10	MN1	MS6
MS	7	73734	D13	MW1	MS7
MS	8	73276	E13	MW1	MS8
MS	9	73667	D13	MW1	MS9
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MS1+…+MS9-MN5**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MW	1	73237	E13	MH10	MW1-(MS4+MS5+MS7+…+MS9)-(MH1+…+MH3+MH6+MH8+MH12+…+MH15+MH17+MH20+MH21)
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MW1-(MS4+MS5+MS7+…+MS9)-(MH1+…+MH3+MH6+MH8+MH12+…+MH15+MH17+MH20+MH21)**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MH	1	76737 (DS)	D20	MW1	MH1
MH	2	75826	D20	MW1	MH2
MH	3	76484	D21	MW1	MH3-MH4
MH	4	76594	D21+D22	MH3	MH4
MH	5	68120	I6	MR11	MH5
MH	6	75559 (DS)	E21	MW1	MH6
MH	8	75586	E22	MW1	MH8
MH	9	65320	F10	MV3	MH9
MH	10	72240	F9	MMV2	MH10-(MW1+MMV1)
MH	12	75071	F16	MW1	MH12
MH	13	75385	F19	MW1	MH13
MH	14	75397	F19	MW1	MH14
MH	15	75449	F21	MW1	MH15
MH	17	75547	F21	MW1	MH17
MH	18	67154 (DS)	G6	MMV2	MH18-MMV4-(MR2+...+MR5+MN7+…+MR11)
MH	19	72193	G7	MMV2	MH19-MMV5
MH	20	75117	G16	MW1	MH20
MH	21	75149	G17	MW1	MH21
MH	22	67994	H4	MR9	MH22
MH	23	68019	H4	MR9	MH23
MH	24	68078	I5	MR11	MH24
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MH1+…+MH6+MH8+…+MH10+MH12+…+MH15+MH17+…+MH24-MW1-(MMV1+MMV4+MMV5)-(MR2+...+MR5+MN7+…+MR11)**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MMV	1	73035	E10	MH10	MMV1
MMV	2	65660	F6	MWWTP	MMV2-(MMT3+MMT4)-(MH10+MH18+MH19)-MR1
MMV	3	65661	F6	MWWTP	MMV3-(MMT5+MMT6+MH9)
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MMV1+…+MMV3-(MMT3+…+MMT6)-(MH9+MH10+MH18+MH19)-MR1**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
MR	1	68361	G6	MMV2	MR1
MR	2	67621	H2	MH18	MR2
MR	3	67638	H2	MH18	MR3
MR	4	67758	H2	MH18	MR4
MR	5	67870	H3	MH18	MR5
MR	7	67979	H4	MH18	MR7
MR	8	67946	H4	MH18	MR8
MR	9	67991	H4 & I3	MH18	MR9-(MH22+MH23)
MR	10	68067	I4	MH18	MR10
MR	11	68077	I5	MH18	MR11-(MR12+MH5+MH24)
MR	12	68106	I5	MH18	MR12
	TOTAL FLOW INTO MSD TREATMENT PLANT:				**MR1+…+MR5+MR7+…+MR11-(MH5+MH22+…+MH24)**

Table 4-4
New Rochelle Sewer District Algorithms

New Rochelle Sewer District Flow Monitoring Locations

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
NPM	1	77923	B2	NN2	NPM1
NPM	2	77810	C2	NN2	NPM2
	TOTAL FLOW INTO NRSD TREATMENT PLANT:				**NPM1+NPM2**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
NMT	1	81561	E7	NL1	NMT1
NMT	2	81110	E8	NN3	NMT2
NMT	3	81244	E5	NN1	NMT3-NL1
	TOTAL FLOW INTO NRSD TREATMENT PLANT:				**NMT1+NMT2+NMT3-NL1**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
NL	1	81327	F4	NMT3	NL1-NMT1
	TOTAL FLOW INTO NRSD TREATMENT PLANT:				**NL1-NMT1**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
NN	1	81218	E4	NRWWTP	NN1-NMT3-~20 houses
NN	2	78719	E4	NRWWTP	NN2-NPM1-NPM2
NN	3	78729	E4	NRWWTP	NN3-NMT2
NN	4	81186	E8	NMT2	NN4
	TOTAL FLOW INTO NRSD TREATMENT PLANT:				**NN1+NN2+NN3+NN4-(NPM1+NPM2)-(NMT2+NMT3)**

Table 4-5
Port Chester Sewer District Algorithms

Port Chester Sewer District Flow Monitoring Locations

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
PRB	1	90735	8	PPC2	prb1
PRB	2	91306	14	PPC2	prb2
	TOTAL FLOW INTO PCSD TREATMENT PLANT:				**prb1+prb2**

Municipality	Meter No.	MH No.	Sheet No.	Flows Into	Total Flow
PPC	2	90063	3	PC WWTP	PPC2
	TOTAL FLOW INTO PCSD TREATMENT PLANT:				**PPC2**

5.0 FLOW MONITORING SYSTEM

5.1 Introduction

To ensure that the flow and rainfall data would be accurate and reliable, thorough research into potential flow monitoring systems was conducted. All-inclusive flow monitoring and telemetry systems, as well as combinations of flow monitors from one manufacturer and compatible telemetry devices from another, were all investigated. Some of the criteria used to evaluate the equipment included, but was not limited to the following:

- Manufacturer’s experience, both with flow monitoring in general, as well as with telemetry technology.
- Manufacturer’s experience with large-scale flow monitoring programs.
- Software capabilities and analysis tools.
- Compatibility of various components (meters, modems, rain gages) from different manufacturers.
- Savin’s experience with the manufacturer.

It was determined that the Teledyne ISCO (ISCO) combined flow monitoring and telemetry system would be well-suited for this monitoring program. This system provided a combination of accuracy, dependability, analysis tools, diagnostic tools, and telemetry.

5.2 Flow Monitors

The 2150 Flow Module measures flow depth with a pressure transducer, and uses continuous wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave and measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow. Both flow depth and velocity were recorded in fifteen-minute increments for the entire duration of the flow monitoring program.

The 2150's area velocity probe is built on digital electronics, so the analog level is digitized in the sensor itself to overcome electromagnetic interference. The probe is also factory-calibrated for a 10-foot span at different temperatures. This built-in calibration eliminates drift in the level signal, providing long-term level stability that reduces recalibration frequency and completely eliminates span recalibration. This is a necessity for a program such as this due to both the quantity of meters as well as the telemetry technology being used.

Some of the standard features of the 2150 include:

- The 2150 is powered by two alkaline batteries within a 2191 Battery Module. This highly efficient power management extends battery life. The chemically resistant epoxy-encapsulated sensor withstands abuse, resists oil and grease fouling, and eliminates the need for frequent cleaning. The quick-connect sensor can be easily removed and interchanged in the field without requiring recalibration.

- Replaceable high-capacity internal desiccant cartridge and hydrophobic filter protect sensor reference from water entry and internal moisture.

- Pressure transducer vent system automatically compensates for atmospheric pressure changes to maintain accuracy.

- Up to four 2150 flow modules can be networked by stacking in order to build a compact, integrated system.

- Secure data storage. All data are continuously stored in flash memory to protect against loss in case of power failure.

- The 2150 measures shallow flow in small pipes. Its low-profile velocity sensor minimizes flow stream obstruction and senses velocity in flows down to 1 inch in depth. For sites with low nighttime flows, flumes were installed to obtain accurate, reliable velocity readings.

5.3 Rain Gages

The ISCO 675 rain gage was used to record rainfall. It is a tipping bucket rain gage that records rainfall at increments of 0.01 inches. Rainfall was recorded at five-minute increments at each of the 12 rain gage locations throughout the four LIS sewer districts for the duration of the flow monitoring program.

5.4 Telemetry System and Data Collection

The use of wireless telemetry allowed for a daily check of all 94 sites from a remote location in minutes. The work orders could then be prioritized to provide field crew visits to the meters and gages requiring immediate attention. The typical telemetry system consists of a cellular modem module and an antenna which is either buried in the pavement adjacent to a manhole for street applications or installed nearby in the woods.

The ISCO 2103ci CDMA cellular modem module is factory-configured to deliver ISCO 2150 flow meter data to a remote server database. Data can also be downloaded from the server using an internet connection. Since the 2103ci modem module uses cell phone technology, a landline modem is not required.

The 2103ci automatically sends data via the internet to a designated server running ISCO Flowlink Pro software. The user-specified primary data transmission interval (5 minutes to 24 hours) can automatically change to a secondary interval when specific site conditions occur at the monitoring site. For the purposes of this monitoring program it was determined that a 24 hour data transmission interval would be used. This means that data is recorded at fifteen-minute intervals by the meter, 24 hours a day, seven days a week. The cell modem subsequently transmits the data from the site directly to the dedicated server once every 24 hours. The meter call-in times were staggered, so as not to overburden the server with calls.

5.5 Flowlink Software

The Flowlink software was designed for both the desktop computer in the office and for the laptop computer in the field. All data are stored in a standard Microsoft Access database that can be viewed in the office application or the field. The software assists field crews with meter configuration, equipment maintenance, and data collection. As a backup to the telemetry system, field crews were able to download data to their laptops as backup.

In the office, Flowlink eliminated the need to export data to a spreadsheet, such as Microsoft Excel, in order to create tables and hydrographs. Flowlink is an all-encompassing software tool. After being transmitted via telemetry from the meter site to the server, data is stored directly in the Flowlink software, thereby making the creation of tables and graphs accurate and reliable.

In addition to the tables and graphs that can be generated, Flowlink software provided several other tools that were beneficial for this program:

- Battery check: one of the biggest concerns with flow monitoring is loss of data due to battery consumption. With Flowlink, field crews could create one template to monitor the batteries at all 94 sites, and have it updated on a daily basis. Similar to an Excel spreadsheet, the columns could be sorted (in this case, by battery voltage) and the crews would create a daily work order of sites requiring battery replacement. This allows for batteries to be changed before voltage drops too far and the telemetry system for that site stops transmitting data.

- Reliability of velocity: Flowlink diagnostics allow the user to confirm whether the velocity is good, reliable data, or if the meter is experiencing a problem (i.e. fouling) and a field crew should be sent out to investigate. There are two velocity diagnostics that could be run concurrently, and again utilize the template function in Flowlink. These diagnostics are the signal strength and the spectrum strength, shown as percentages. The template was setup so that flow rate, level, velocity, signal strength and spectrum strength could be plotted together on one graph. The velocity signal measures the amount of particles in the waste stream. If a probe is fouled, then there are no particles to measure velocity, and the signal strength drops dramatically. The velocity spectrum is a “noise level” reading/indicator. Smooth laminar flow would give higher percentages than choppy or turbulent flows.

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6.0 DATA QUALITY ASSURANCE AND QUALITY CONTROL

6.1 Pre-installation Verification

As with any flow monitoring program, QA/QC of the meter data is of the utmost importance. Extensive steps were taken to ensure that the data collected was both accurate and reliable. Prior to meter installation, both office and field verifications of the proposed flow monitoring locations and equipment were conducted. These QA/QC checks included the following:

- Municipal boundary and meter locations check: as stated previously in this report, the key manholes were selected based on sewer system maps provided by the County. Savin's procedure for key manhole selection included locating and highlighting all municipal borders, locating any sewers flowing from one municipality into another, and then selecting the first manhole downstream of the municipal boundary as the key manhole. A senior engineer at Savin was responsible for locating these key manholes, and subsequently, four other engineers/office personnel followed the same protocols and located the same 82 key manholes.

- Algorithm check: the location of the flow meters was used to develop algorithms, which were used to calculate flow rate for each municipality. The flow rates were calculated using both Flowlink and by manual calculation to ensure there were no errors. Both methods provided the same results.

- Comparison of official municipal boundaries against boundaries shown on the sewer system maps. Municipal boundary reliability is extremely important when designating key manholes for flow monitoring. If the boundary is shown to be in the wrong location, the flow meter could be installed in an incorrect manhole that is located in the wrong municipality. Municipal boundaries were cross-checked against the boundaries shown on the sewer maps and found to be in agreement.

- Pump station flows: Westchester County provided a list of all County-owned pump stations in the study area. A field crew conducted field investigations at each of these pump stations, as well as other local pump stations (found in the field by the crews) and confirmed the tributary area and discharge locations, and determined that there were no flows unaccounted for and that the flows had been attributed to the correct municipality.

- Significant industrial users: A list of facilities categorized as a significant industrial user was provided by the County. One of these significant industrial users was located within the LIS sewer districts and has an insignificant flow rate. Therefore, it was determined that there are no industrial facilities that discharge large quantities of wastewater that could skew the results.

6.2 Field Verification

Once the flow meters were installed, field crews continued QA/QC efforts by conducting the following field verification checks:

- Routine site maintenance: during all site visits, the field crew would check that the manual depth and velocity readings matched the flow meter's logger readings, and calibrate the meter, if necessary. Other routine maintenance included cleaning the sensors regularly, changing desiccant and ensuring that the cables were tied in place and that the sensors were firmly in place in the proper position.

- Telemetry spot check: During site visits, crews would download all data since the previous download to their computer. Since data was continuously being transmitted from each of the 94 sites to the servers, office personnel would randomly check that the data downloaded on the crew chief's computer matched data that was being transmitted to the servers. Data matched 100% of the time.

- Crews confirmed in the field that each of the 82 meters were installed in the correct manholes and in the correct lines. They also confirmed silt levels and probe offsets (if necessary) were calculated correctly in the Flowlink software.

6.3 Comparison to WWTP Meters

Once all of the boundaries and algorithms were checked and the meters were installed, a comparison was conducted between the County plant meters and the temporary meters installed in the sewers. In order to accomplish this task, Westchester County calibrated its meters at each of the four LIS Wastewater Treatment Plants. The County plant meters were calibrated between May and August 2009.

Once the calibrations were completed, the County provided the monthly flow data for each of the four LIS Plants. The daily average flow as measured by the County plant meters was then continuously compared to daily average plant flows calculated from the meters in the sewer system. The results of this comparison can be seen in the individual hydrographs for each plant in Figures 6-1 through 6-4. The meters correlated well with the plant meters.

6.4 Supplemental Meters

As a follow-up to the County plant meter comparison, an additional check of meters was conducted by installing supplemental meters at each of the nine sewer system meter locations (two at Mamaroneck, three each at New Rochelle and Blind Brook, and one at Port Chester) in order to further confirm accuracy. These supplemental meters were installed for a two-month period between February 22, 2010 and April 20, 2010, in the same manholes as the original plant meter sites. The data from all nine supplemental meters tracked well with the original meters. Sample hydrographs for one meter comparison at each wastewater treatment plant is included in Figures 6-5 through 6-8.

In addition to these nine supplemental meters, other supplemental meters were installed at an additional 19 locations, for a total of 28 of the 82 (34%) metering sites. Each of these supplemental meters also tracked well with the corresponding original meter.

Figure 6-1

Blind Brook WWTP - Sewer System and Plant Meter Comparison

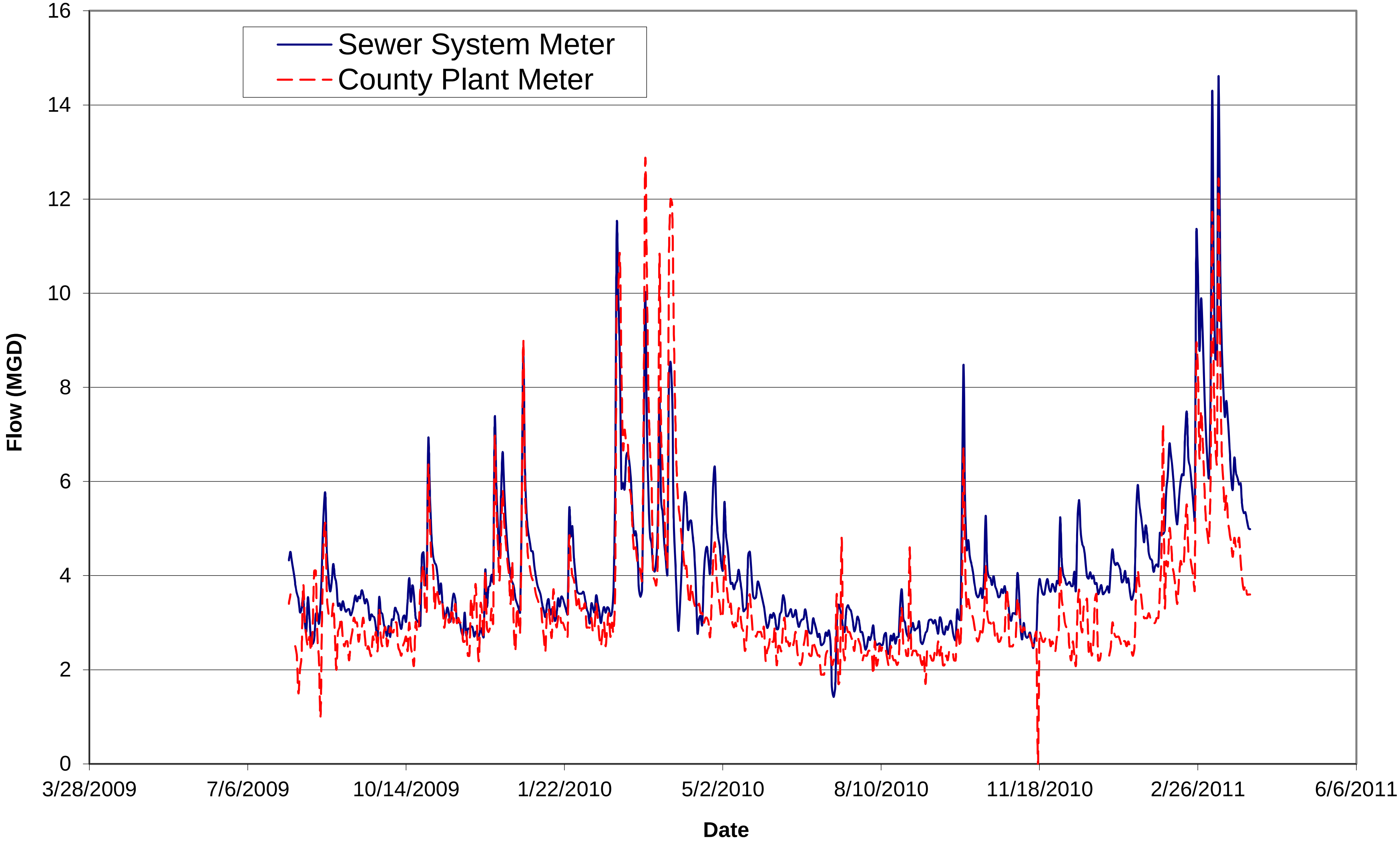


Figure 6-2

Mamaroneck WWTP - Sewer System and Plant Meter Comparison

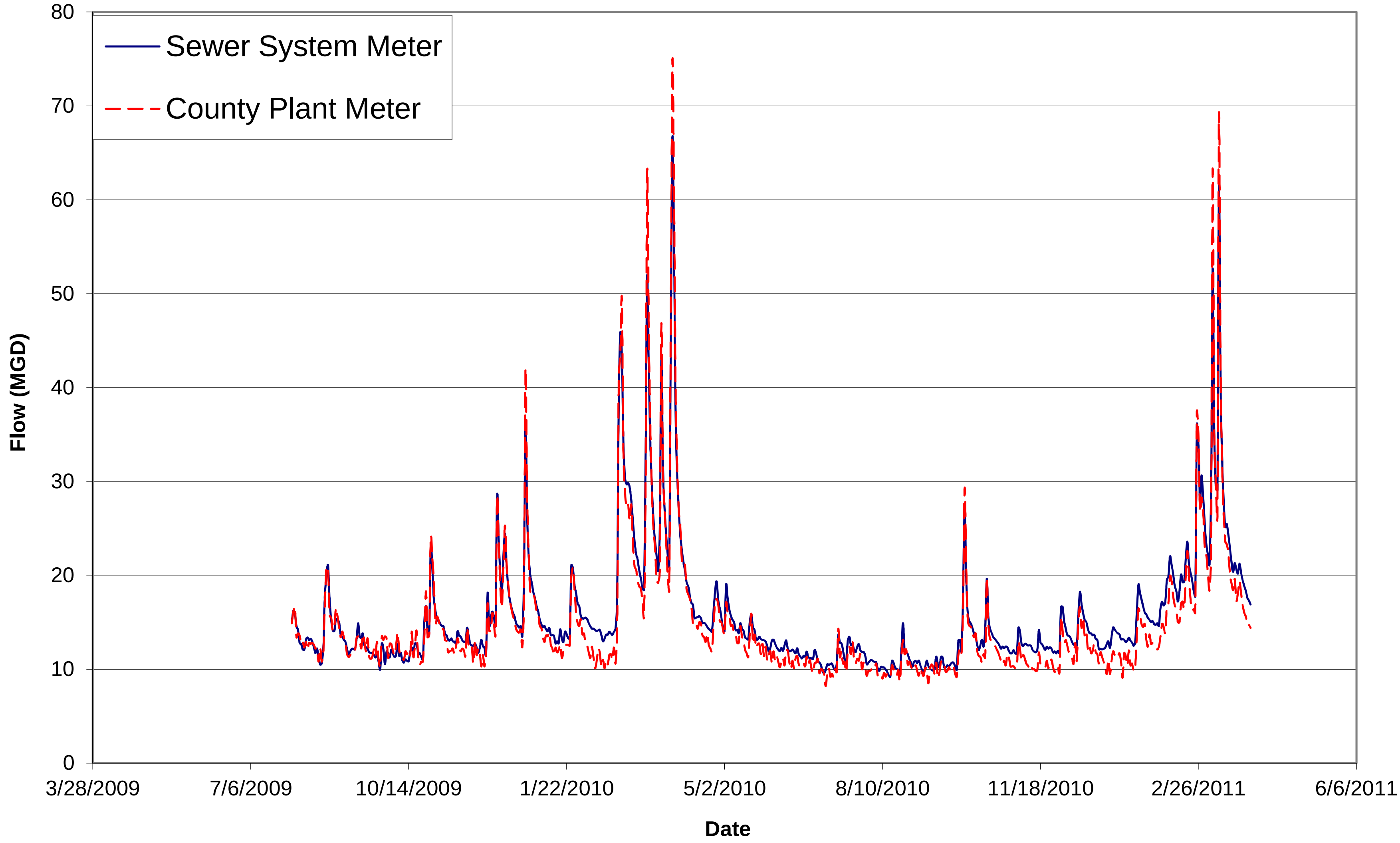


Figure 6-3

New Rochelle WWTP - Sewer System and Plant Meter Comparison

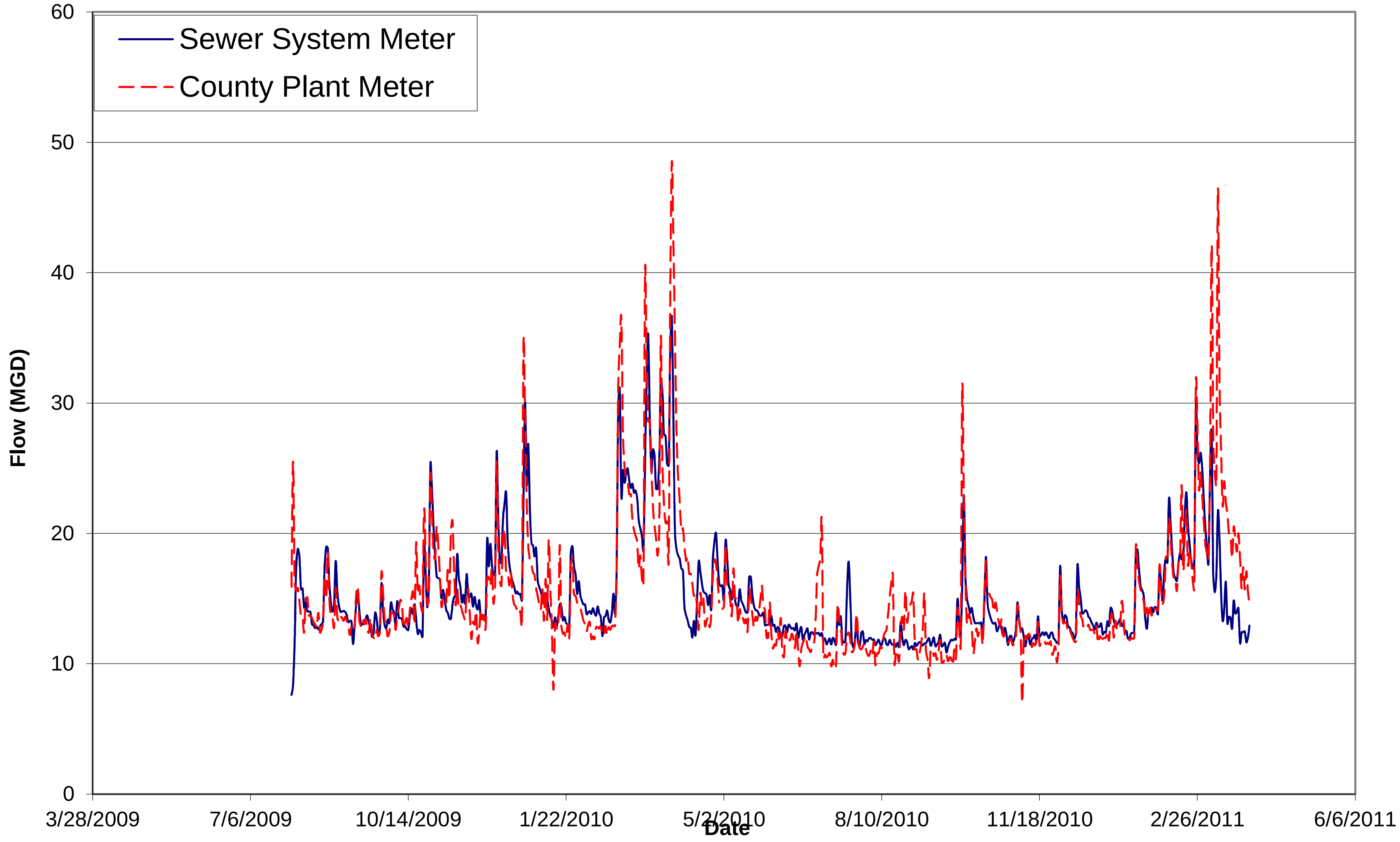


Figure 6-4
Port Chester WWTP - Sewer System and Plant Meter Comparison

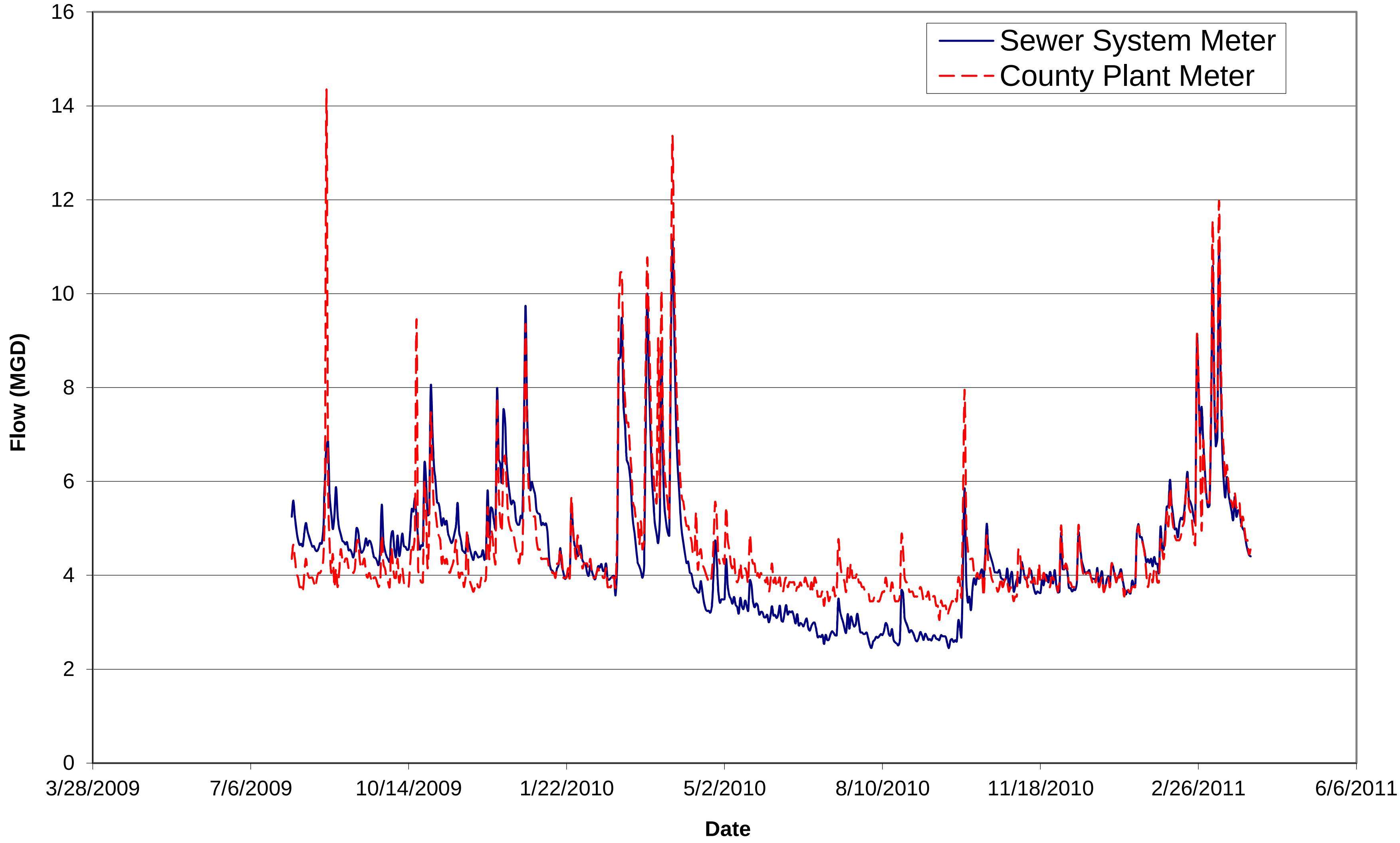


Figure 6-5

Blind Brook WWTP - Comparison with Supplemental Meters

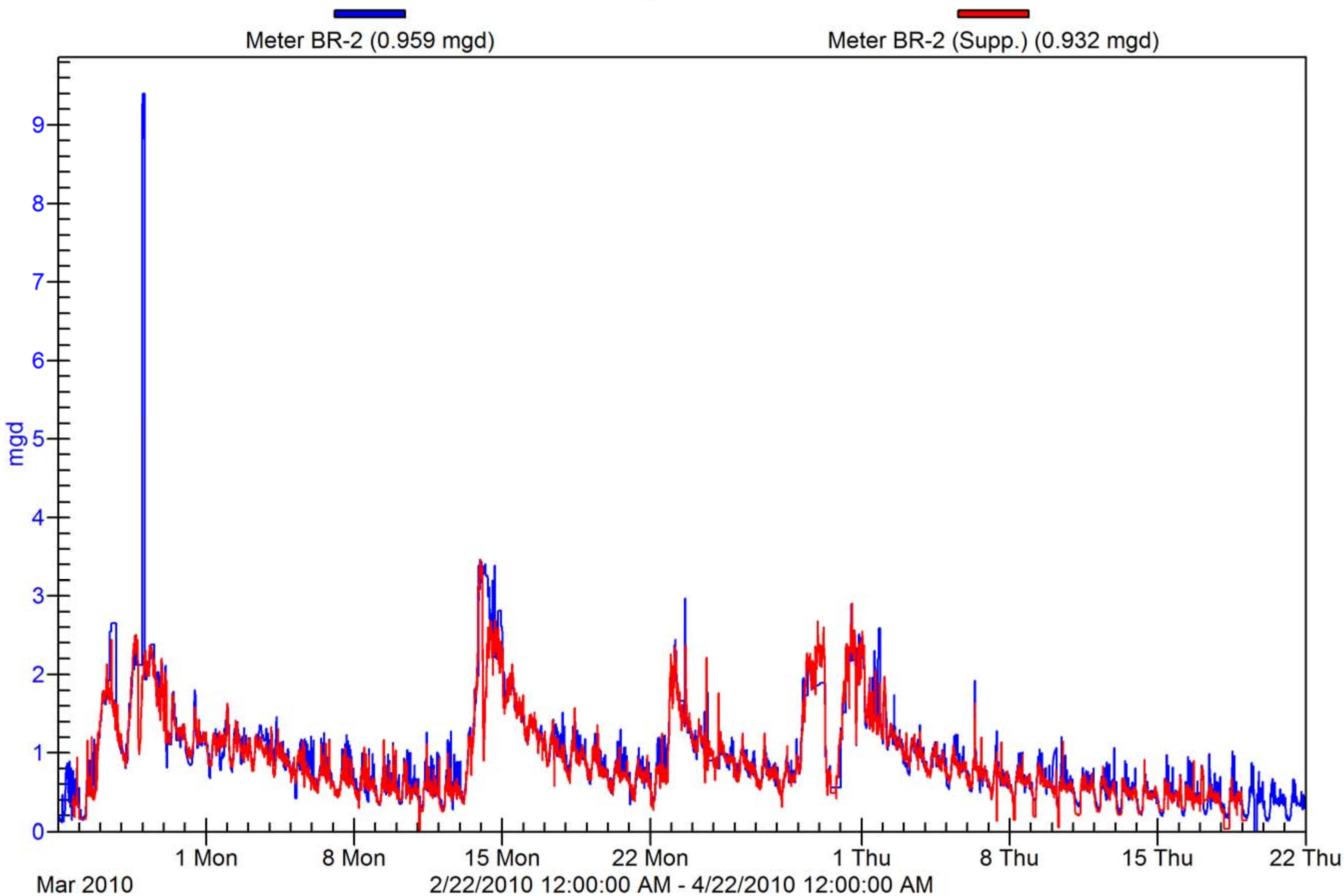


Figure 6-6

Mamaroneck WWTP - Comparison with Supplemental Meters

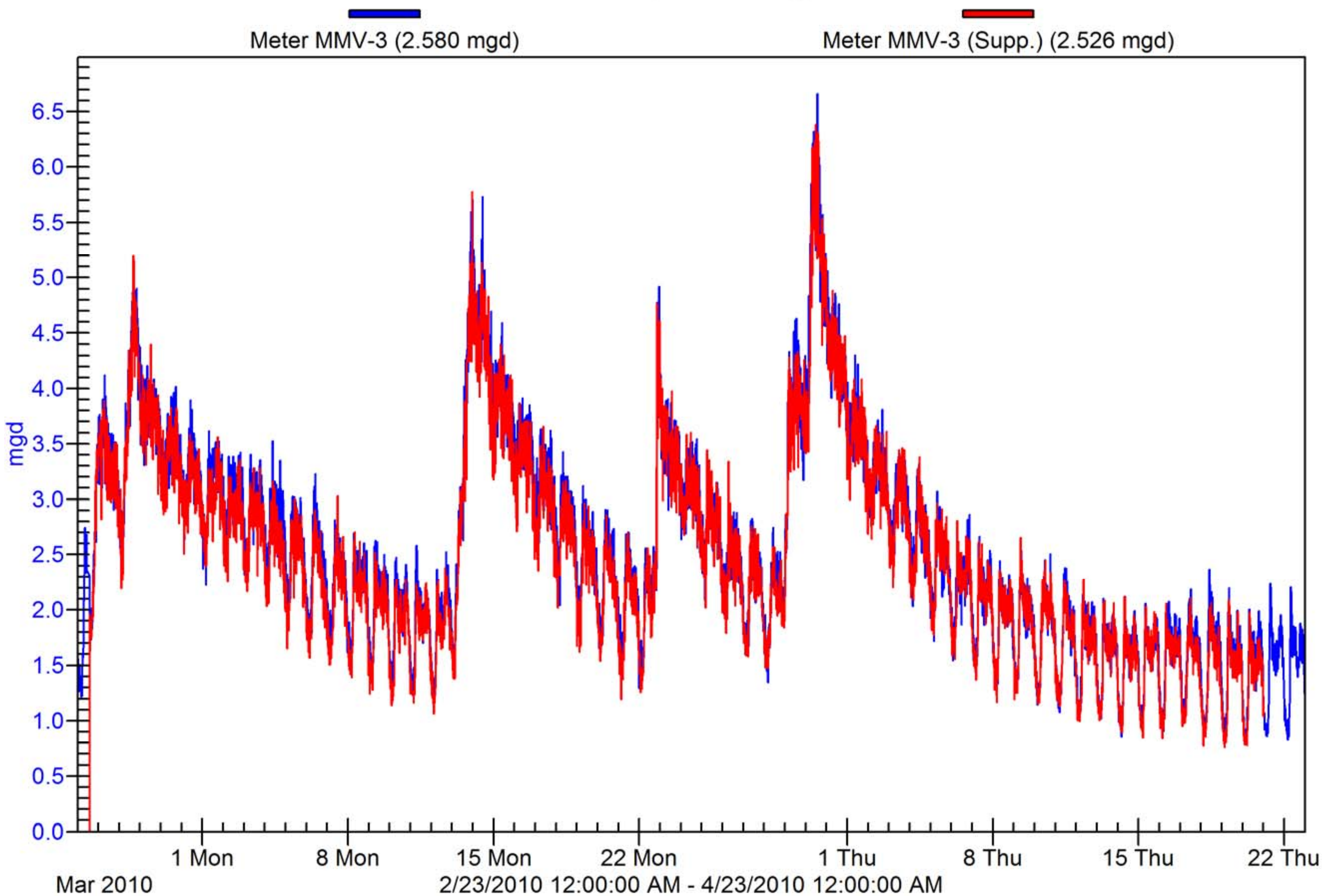


Figure 6-7

New Rochelle WWTP - Comparison with Supplemental Meters

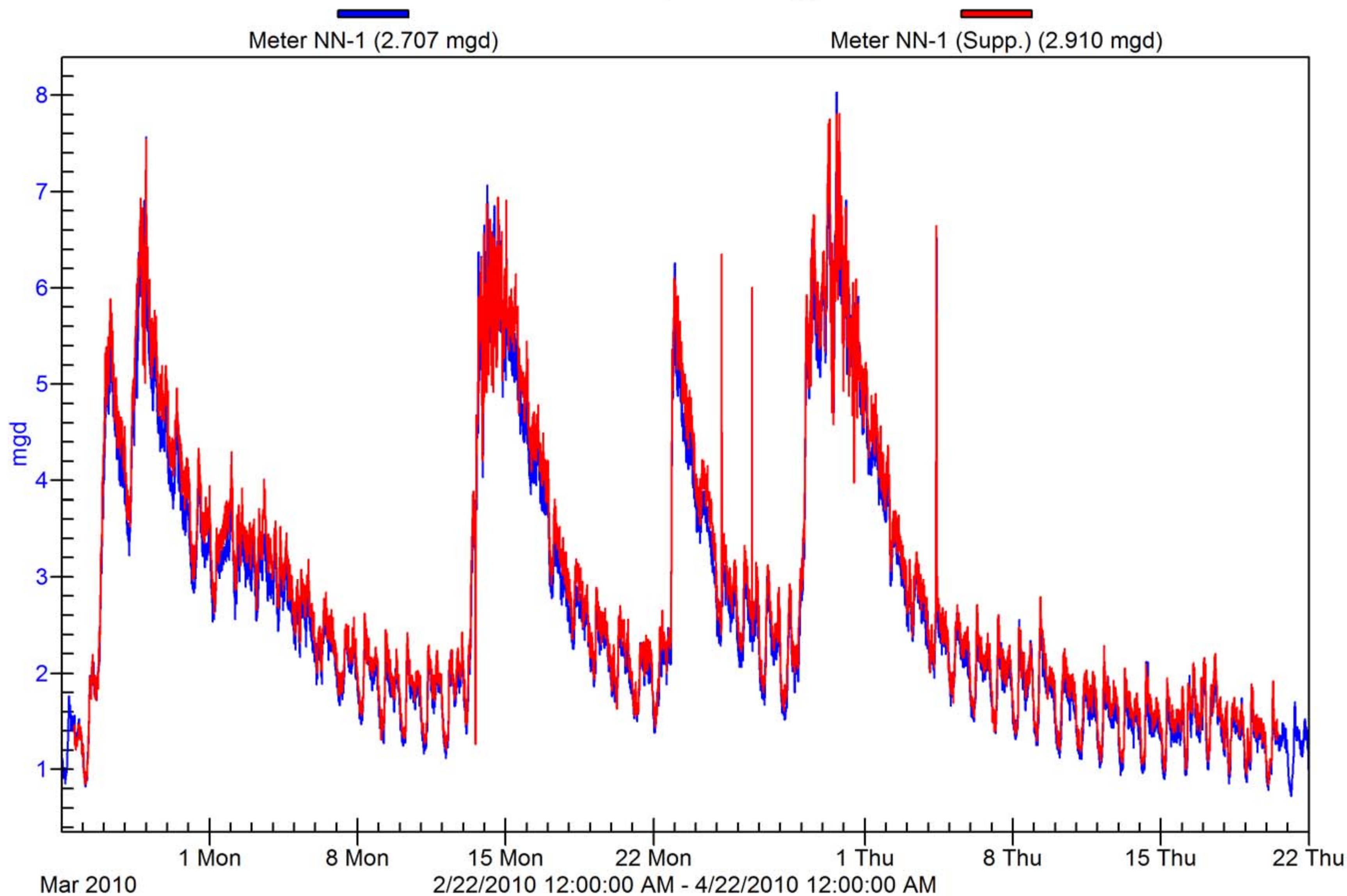
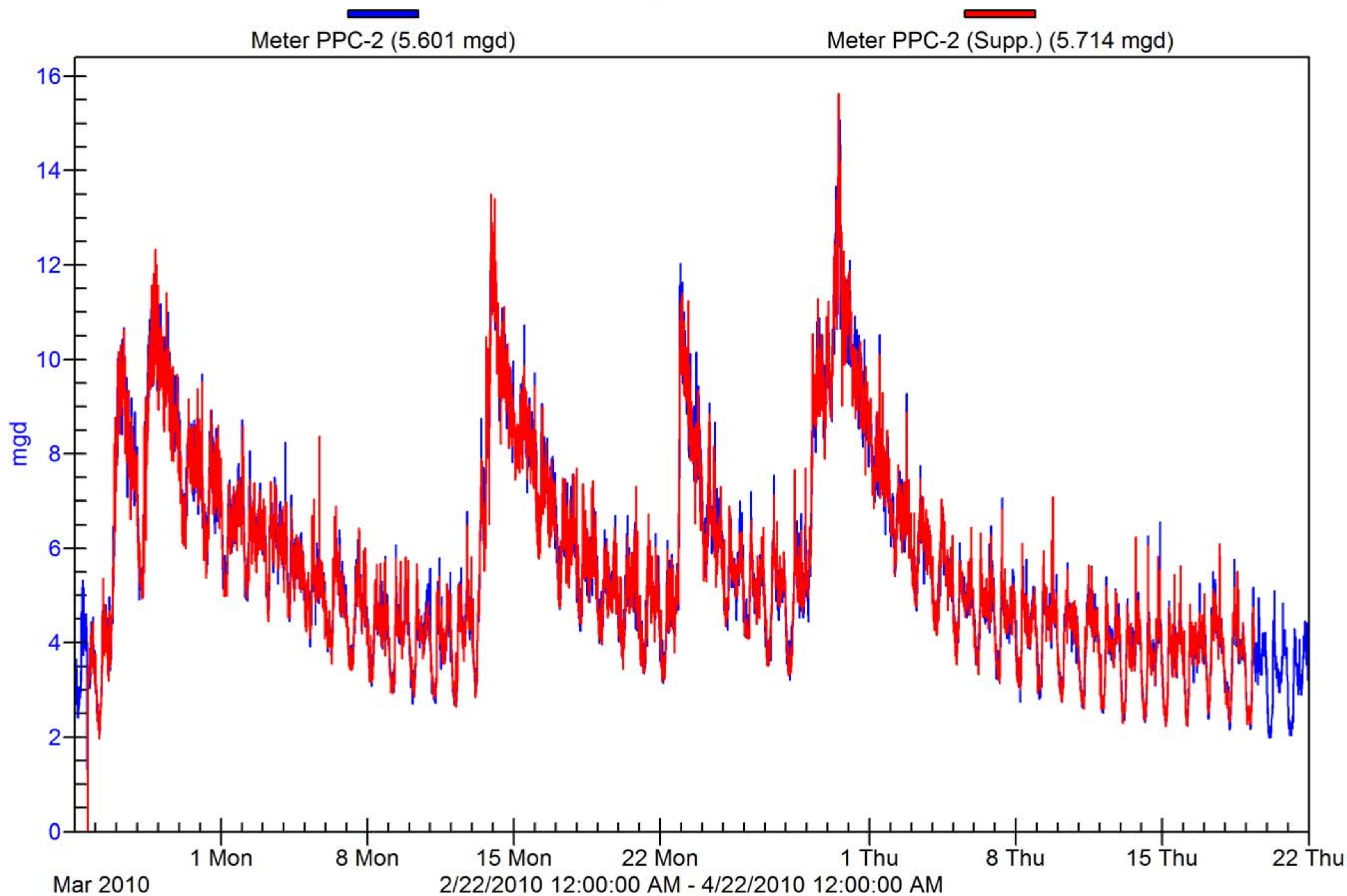


Figure 6-8

Port Chester WWTP - Comparison with Supplemental Meters



7.0 POPULATION ESTIMATES

7.1 Municipality Populations

Section 4 of this report detailed the steps taken to determine the flow rates for each of the 11 municipalities that discharge to the Long Island Sound sewer districts. The final component that was needed to determine the daily average per capita flow rates was a population estimate for each municipality. Table 7-1 shows that eight of the 11 municipalities discharge solely to one of the LIS treatment plants. The remaining three municipalities also discharge to one of the Yonkers Joint Sewer Districts. Therefore, two separate methodologies were necessary to determine the populations.

Populations for Municipalities Entirely Within the LIS Sewer Districts

The Westchester County Department of Planning provided 2010 census data to be used for population estimates for each of the eight municipalities that discharge solely within the confines of the four LIS sewer districts. Table 7-1 shows the population estimates used for each municipality.

Populations for Municipalities that also Discharge to the Yonkers Joint Sewer District

Since the population estimates from the Department of Planning are based on entire municipalities, these numbers could not be used for White Plains, Scarsdale and Pelham Manor, since a portion of each of these municipalities also discharge to the Yonkers Joint Sewer Districts. For these three municipalities, population estimates were based on block and lot census tracts and individual house counts.

The LIS sewer district and municipal boundaries were superimposed onto the census tract maps and the number of houses in each municipality outside of the LIS districts was counted. The *Westchester County Department of Planning Databook* also provides an average household size for each municipality in Westchester County. Once the total number of houses had been quantified for each municipality, that number was multiplied by the average household size (2.5 for White Plains, 2.9 for Pelham Manor and 3.1 for Scarsdale) to determine the population residing outside the LIS sewer district portion of that municipality. These numbers were used for the per capita flow rate calculations, and are summarized in Table 7-1.

7.2 Commuter Allowance

Section 824.72.3 of the Westchester County Environmental Facilities Sewer Act states that "Municipalities identified by the Westchester County Commissioner of Planning as having more than 1,000 additional daytime commuter residents, flow of 30 gallons per daytime commuter may be permitted at the discretion of the Commissioner of Department of Environmental Facilities upon application of the municipality". Table 7-2, provided by the Department of Planning, demonstrates that each of the 11 municipalities has at least 1,000 commuters on a daily basis. An allowance of 30 gallons per day per commuter in each municipality was incorporated into all weekday per capita flow rate calculations. This allowance was not incorporated into the weekend flow rate calculations.

For the eight municipalities discharging only within the LIS Sewer districts, this credit was a simple calculation: 30 gallons per day per commuter multiplied by the total number of commuters. The resulting flow rate, in gallons per day, was then subtracted from the daily average flow rate. The net flow rate was then divided by the total number of residents to obtain the final per capita flow rate for each municipality.

For the remaining three municipalities, a ratio of the population within the LIS sewer district to the total municipal population was taken, and applied to the total number of commuters. The estimated number of commuters was then used in the calculation described above to determine the per capita flow rate for these municipalities.

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Table 7-1
Poulation Estimates

Municipality	**Population**
Port Chester	28,195
Rye Brook	9,599
New Rochelle	73,260
Larchmont	6,587
Town of Mamaroneck	10,698
Harrison	26,504
Rye	15,242
Village of Mamaroneck	18,456
Pelham Manor*	3,272
Scarsdale*	5,816
White Plains*	25,759

*Partial populations. Portion of population shown is for Long Island Sound sewer districts only. The balance of the population contributes to the Yonkers sewer district.

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Table 7-2
Daytime Populations for Municipalities in LIS Sewer Districts

Municipality	Primary Jobs			Workers			Daytime Population Difference	2009 Population	Daytime Population
	Total	Held by residents	Held by non-residents	Total	Work in municipality	Work outside of municipality			
White Plains	51,451	4,877	46,574	22,838	4,877	17,961	28,613	57,442	86,055
Harrison	22,649	1,393	21,256	8,048	1,393	6,655	14,601	26,504	41,105
Rye Brook	6,283	259	6,024	2,892	259	2,633	3,391	9,599	12,990
Rye (City)	7,415	659	6,756	4,344	659	3,685	3,071	15,242	18,313
Mamaroneck (Town)	10,450	1,415	9,035	8,779	1,415	7,364	1,671	29,154	30,825
Larchmont	2,773	165	2,608	1,676	165	1,511	1,097	6,587	7,684
Mamaroneck (Village)	7,614	1,007	6,607	6,574	1,007	5,567	1,040	18,456	19,496
Rye (Town)	15,812	2,625	13,187	15,046	2,625	12,421	766	45,238	46,004
Pelham Manor	2,199	120	2,079	1,827	120	1,707	372	5,464	5,836
Scarsdale	4,250	350	3,900	5,061	350	4,711	-811	17,755	16,944
Port Chester	8,017	1,347	6,670	9,373	1,347	8,026	-1,356	28,195	26,839
New Rochelle	22,072	5,732	16,340	26,761	5,732	21,029	-4,689	73,260	68,571

Prepared by Westchester County Department of Planning using US Census LED OnTheMap Version 4, 2008 data. 2009 Population is 2009 projected Census estimate.

8.0 MUNICIPALITY FLOW RATES

8.1 Per Capita Flow Rates

The main objective of this flow monitoring program was to determine which, if any, municipalities exceed the 150 gallons per capita per day flow rate limit. As stated previously in this report, the flow monitoring software took the 82 flow meters spread throughout the 11 municipalities and combined them, using the aforementioned flow algorithms, into 11 individual meter sites. This resulted in one flow rate for each municipality that would be used for all analyses.

Daily average flow rates were calculated based on the combined 15-minute flow metering data for each municipality. The final per capita flow rates were then calculated by subtracting the commuter allowance for each municipality from the daily average flow rate, then dividing by the population estimate for that municipality. The commuter allowance was only applied to weekday flow rates (Monday through Friday), and not weekend flow rates. Hydrographs for each of the 11 municipalities (based on the final per capita daily average flow rates with the commuter allowance) are shown in Appendix A.

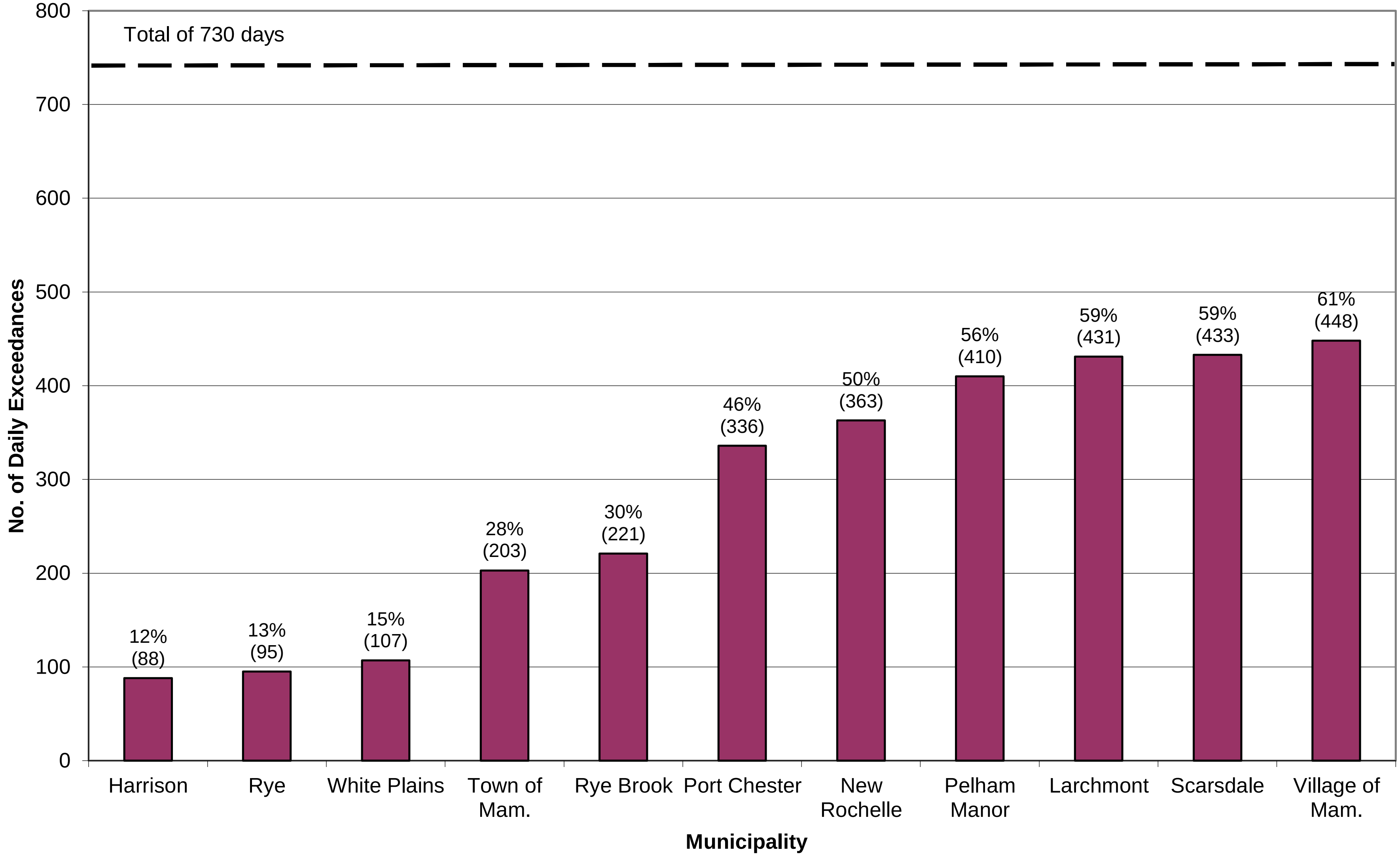
Appendix B contains rainfall graphs for each of the 12 rain gages. Rainfall was recorded over the course of the two-year monitoring period to ensure that the flow meter data was representative of various conditions such as prolonged dry periods, prolonged wet periods, snow melt, high groundwater, low groundwater, rainfalls of large and small volumes, and rainfalls of high and low intensity. Approximately 25 storm events were analyzed, with rainfall of 0.51” to 3.51”, a duration of 1 hour to 37 hours and return periods ranging from 0.2 years to 7.8 years.

8.2 Compliance with Westchester County Ordinance

Section 824.72.2 of the Westchester County Environmental Facilities Sewer Act states that "Excessive infiltration and inflow means the quantity of flow entering the County sewer system which is greater than 150 gallons per capita per day". Since this is an allotment per day, Section 824.21, paragraph 17 defines "day" as a calendar day from midnight to midnight. There is a text box on each of the 11 hydrographs in Appendix A that provides the total number of days that exceeded the 150 gpcd limit during the 730 day monitoring period. Each graph has a dark horizontal line at the 150 gpcd rate, therefore all flow rates above this line are in excess of the Sewer Act limit.

This data is further summarized in bar chart form in Figure 8-1. Each bar in the figure shows the total number of days and percentage of time that each municipality exceeded the 150 gpcd limit during the 730 day monitoring period. The 11 municipalities exceeded the limit between 12% and 61% of the time.

Figure 8-1
Summary of Daily Exceedances



9.0 FLOW REDUCTION STRATEGIES

9.1 Introduction

There are several methods that have been used successfully to reduce extraneous infiltration and inflow into public sewer systems. These methods include identifying and reducing I/I from the public sewers such as defective manholes and defective sewers in the public domain. Effective I/I reduction programs also include identifying and reducing I/I from private sources such as basement sump pumps and roof leaders that discharge into public sewers and rehabilitation of defective private service laterals. The various methods that can be used to identify and reduce I/I from public and private sources are described below.

9.2 Sewer System Evaluation Surveys

A sewer system evaluation survey (SSES) is a methodical step-wise approach to quantify sewage flow rates in a sewer system, identify areas of the system that have higher rates of infiltration and inflow, and to identify and quantify the specific defects that are the sources of the I/I. The I/I sources are then prioritized in terms of their relative I/I contribution. Rehabilitation methods and cost estimates are then developed for each specific I/I source. The steps in an SSES program are as follows:

9.2.1 Flow Monitoring

The first step in an SSES program is to conduct flow monitoring of the sewer system to quantify flow rates during dry weather and wet weather. Flow monitoring during dry weather allows determination of base flow (the normal sanitary sewage flow from residential, commercial, and industrial sources) and infiltration (flow from clean groundwater that enters the sewer system through defective sewers, defective laterals, and defective manholes). Flow monitoring during wet weather allows determination of the direct inflow (clean rainwater that enters the sewer system from direct connections to catch basins, roof leaders and similar sources), indirect inflow (rainwater that enters the sewers from cross-connections with the storm sewers), and rainfall-derived infiltration and inflow (RDII, clean water that enters the sewers from sump pump discharges and other sources that are subject to increased groundwater levels from the rainfall).

In general, flow monitoring for SSES programs is conducted for 12 to 16 weeks, depending on the rainfall characteristics captured including the number of rainfall events, total rainfall, and rainfall intensity. Flow monitors are placed at key manholes to measure flow from sub-areas that consist of approximately 20,000 linear feet of sewer. Data is collected on a regular basis and analyzed to determine the various components such as daily average flow, peak daily flow, base flow, infiltration, inflow, and rainfall derived infiltration. The infiltration and inflow from each sub-area are prioritized in order to guide more detailed investigations to identify specific sources of infiltration and inflow.

9.2.2 Flow Isolation

Flow isolation, or nighttime weiring, is used to identify manhole-to-manhole sewer segments that exhibit higher rates of infiltration based on the flow monitoring data. Calibrated weirs are inserted in the downstream sewer segment during periods of low sanitary flow and dry weather. Flow isolation is done at night (typically between midnight and 6 am) so that there is minimal sanitary sewage present. It is also done during dry weather to eliminate the influence of rainfall. Instantaneous readings are taken from the weirs and used to calculate an infiltration rate in each sewer segment. The segments that have higher rates of infiltration are scheduled for closed circuit television inspection (CCTV).

9.2.3 Closed Circuit Television Inspection

The individual sewer segments that show higher rates of infiltration are inspected with CCTV. CCTV allows the operator to identify and quantify specific defects in the sewers that contribute to infiltration. For example, CCTV allows the operator to identify an offset joint 47 linear feet from a reference manhole that is contributing three gallons per minute of infiltration. The CCTV inspection is digitally recorded on DVD with the operator's audio narrative description of his observations. The entire CCTV operation is done in accordance with standardized protocols developed by the National Association of Sewer Service Companies (NASSCO). The data gathered from CCTV inspection can be tabulated and prioritized for rehabilitation.

9.2.4 Manhole Inspection

Manhole inspection is used in sub-areas that exhibit higher rates of both infiltration and inflow. Defective manholes can contribute infiltration through leaking walls, leaking benches, defective connections to the sewers, and other similar sources. Defective manholes can contribute inflow from holes in the cover, cracks around the frame, and other similar sources. Manholes are usually inspected using a prescribed methodology developed by NASSCO, depending on the level of detail required. Data from the visual inspections is tabulated and prioritized for rehabilitation.

9.2.5 Smoke Testing

Smoke testing is used in sub-areas that exhibit higher rates of inflow to identify specific inflow sources such as roof leaders, catch basins, area drains, window well drains, and similar sources. A non-toxic smoke specifically developed for sewer system investigations is blown into the sanitary sewers. The smoke, which is under slight pressure, will be emitted from all open sources that are connected to the sanitary sewers. A field crew will observe all smoke emissions and document the ones from illicit sources such as roof leaders and storm drains. The field crew also characterizes the surrounding area (blacktop, grass, etc) so that a run off coefficient can be assigned. The drainage area of the inflow source is estimated. The quantity of inflow can be estimated from the drainage area, run off coefficient, and quantity of rainfall. The data is tabulated and prioritized for rehabilitation.

9.2.6 Dyed Water Testing

Dyed water testing is used to identify suspected inflow sources that did not emit smoke during the smoke testing program. Suspected sources typically include roof leaders that discharge directly into the ground, driveway drains, roof drains, and other inflow sources that may be blocked with debris or standing water. The procedure consists of adding water mixed with a fluorescent dye to the suspected inflow source. The downstream sanitary and storm drain manholes are opened and observed for presence of the dyed water. If the dyed water shows in the sanitary manhole, it is concluded that the suspected inflow source is connected to the sanitary system. The field data is tabulated and prioritized for rehabilitation.

9.2.7 Dyed Water Flooding

Dyed water flooding is another technique used to identify and quantify inflow from cross-connections between the sanitary sewers and the storm drains. Typically, these cross-connections are discovered during smoke testing when a small amount of smoke is seen coming from a crack in the street or sidewalk, from a grassy area, or from a catch basin. Cross-connections occur when the sanitary sewer and storm drain are in close proximity and there are defects in both systems that allow the storm water to exfiltrate from the storm drain and enter the sanitary sewer. It is also possible that sewage can exfiltrate from the sanitary sewers and enter the storm sewers, causing contamination. Dyed water flooding consists of adding dyed water to the storm system and observing the sanitary system. If dyed water shows in the sanitary system, CCTV is used to identify the specific location in the sanitary sewer where the dyed water is entering. The amount of inflow from the cross connection is also estimated. Data is tabulated and prioritized for rehabilitation.

9.3 Sump Pump Disconnection

Sump pumps are used to discharge water that collects in low lying areas of residences, commercial establishments and industrial facilities, garages, and other similar locations. The water collected in the sump is usually due to high groundwater that leaks through the building foundation. The high groundwater levels can be due to snow melt in the spring, tidal influence, or rainfall that percolates through the soil. The sump pumps are supposed to discharge to the storm drains, on the ground surface, or into a dry well on the property. However, it is well known that many sump pumps discharge directly into the sanitary sewers. During periods of sustained high groundwater, the sump pumps can run continuously for several days.

Sump pumps that discharge into the sanitary sewers should be disconnected and redirected to discharge to other locations. A visual inspection of the interior plumbing of a building can be conducted to determine if the sump pump is connected to the sanitary sewer. If the plumbing is behind a finished wall it may be necessary to activate the sump pump with dyed water and determine the discharge location by observing downstream sanitary and storm manholes, discharges at the curb, dry wells, and other locations.

9.4 Public and Private Lateral I/I

It is estimated that in many sewer systems, service laterals comprise approximately 50 percent of the total length of sewer. It has also been observed that a significant quantity of infiltration and RDII is directly attributable to defects in the service laterals. Service laterals are subject to the same defects as mainline sewers – poor construction methods, improper connections, deterioration of the joints connecting the individual segments, offset joints, cracks, root penetrations, etc. The public portion of the service lateral is usually considered from the connection to the mainline sewer up to the property line. The private portion of the lateral is usually considered from the property line up to the building.

Service laterals can also be inspected with CCTV equipment to identify defects and quantify infiltration. One method of CCTV consists of inserting the camera in the lateral cleanout. The camera is mounted on flexible rods that can be pushed through the lateral out to the mainline sewer. The other method of CCTV consists of launching the camera from the mainline sewer up the lateral. Both methods allow for identification of physical defects and sources of infiltration. The inspection can be digitally recorded similar to the CCTV of the mainline sewer.

9.5 Sewer System Rehabilitation

There are numerous methods and proprietary products available to replace or rehabilitate mainline sewers, private laterals, manholes, and inflow sources. Some of the more common methods are described below.

9.5.1 Mainline Sewer Rehabilitation

Excavation and Replacement

Sewers that are crushed or badly broken and have no structural integrity must be excavated and replaced. The entire sewer segment from manhole-to-manhole can be replaced if the condition warrants. Alternatively, if only a small section of pipe needs replacement the work can be limited to the location of the specific defect.

Pipe Bursting

Pipe bursting is a trenchless technology that is used to replace an entire manhole-to-manhole segment of sewer because it has significant structural defects, or to increase the size of the existing sewer to provide additional hydraulic capacity. Pipe bursting consists of inserting a device in the sewer that expands under hydraulic pressure and bursts the existing pipe. The old sewer is left in place and the new sewer is installed from a pit at one of the manholes.

Cured in Place Pipe Lining (CIPP)

Cured in place pipe lining is an established method to rehabilitate sewers with defects that lead to RDII. During this process, a resin-impregnated fabric is inserted into the existing pipe from a manhole. The fabric is cured with hot water, steam, or ultra violet light. The cured liner seals the inside of the existing pipe and prevents RDII from entering the system. The connections to the service laterals are opened with a cutting tool after the liner has cured. The annular spaces at the lateral connections and connections to the manholes are usually sealed with grout after the liner is installed to provide a completely sealed system.

CIPP can be used to rehabilitate the entire sewer segment and for small sections with individual defects. The segmental liners used for individual defects are called segmental liners and usually come in sections as short as four feet.

Grouting

Grouting is another established method used to seal sewer defects such as offset joints, circumferential cracks and fractures. During this process, the grouting device is inserted into the sewer along with a CCTV camera. The device is situated to surround and isolate the defect. A polymeric grout is then injected under pressure into the defect, providing a waterproof seal.

9.5.2 Service Lateral Rehabilitation

Most of the same methods used for mainline sewer rehabilitation are also used to rehabilitate service laterals. Excavation and replacement is used to repair laterals that have severe structural defects, such as crushed pipe or completely dislocated and offset joints. CIPP is used to rehabilitate laterals with cracks, fractures, breaks, and offset joints. The liners can be used to seal the lateral from the cleanout all the way to the mainline sewer, or from the mainline sewer up the lateral a few feet. Some of the lateral liners extend into the mainline sewer to provide a seal around the annular connection at the sewer-lateral interface. Grouting is also used either alone or prior to CIPP to seal offset joints, fractures, and connections to the sewer.

9.5.3 Manhole Rehabilitation

Manholes can be a significant source of RDII through defects such as cracked frames and covers, offset frames and covers, cracks in the walls, bench or trough, missing bricks and deteriorated mortar, and improper covers. Some of the rehabilitation methods are as follows:

Frame and Cover Rehabilitation

RDII can enter the manholes through improper covers such as a storm drain cover, a cover that is not the correct size, or a cover that is below grade and subject to ponding. Cracks in the frame and cover or an offset frame and cover can also be sources of RDII. Improper covers or covers that are the wrong size or cracked should be replaced with the correct type of cover. Cracked frames and offset frames should be replaced or positioned correctly over the top of the manhole. Manholes that are below grade and allow RDII to enter through the cover or frame should be raised to the proper height.

Point Repairs

Point repairs are used to rehabilitate manholes with specific, individual defects such as missing bricks, localized cracks in the walls or bench, and open joints in precast manholes. Grout is used to repair the individual defects and prevent further RDII.

Manhole Lining

Lining of the entire manhole is used when the defects are widespread and point repairs are not appropriate. Liners can be cement, epoxy or polymer, or the cured in place type, similar to CIPP for sewers. Cement lining is used to seal the entire interior of the manhole to repair widespread cracks, missing mortar, and loose bricks. A cement lining is used when the manhole is not subject to corrosion from hydrogen sulfide. An epoxy or polymer liner is used to seal the interior of the manhole when corrosion is present. The cement and epoxy liners can be sprayed or brushed on the manhole walls. Cured in place liners are also used to seal the interior of manholes and to provide some structural support.

Manhole Replacement

Manholes that are severely defective and have lost their structural integrity need to be replaced. Typically these manholes are subject to severe and prolonged corrosion from hydrogen sulfide gas escaping from the wastewater. Methods to protect the interior of the manhole or reduce the corrosion should be incorporated into the replacement process.

9.5.4 Inflow Rehabilitation

In addition to defective manholes and sump pumps, inflow can enter the sewer system through direct sources such as roof leaders, catch basins, driveway drains, and similar sources. These inflow sources can be eliminated by removing the direct connection to the sewers and routing the discharge to the storm drains or to the ground. Catch basin connections can be eliminated with a concrete plug. Roof leaders can be cut at ground level and directed to the surface or a dry well. Driveway drains, area drains and other similar inflow sources need to be disconnected, plugged, and directed to another appropriate discharge location.

9.6 Building Inspection and Certification

Another method to ensure that I/I from private sources is reduced or minimized is to enact a building inspection and certification program. Building owners would be required to have their property inspected by a competent individual such as a licensed plumber or professional inspector and certified that all sources of I/I have been eliminated. The program would include inspection of I/I sources such as sump pumps, roof leaders, roof drains, area drains, driveway drains, building laterals, and all other potential sources of I/I. If no sources of I/I are found, the property owner would have to provide certification to that effect. If any connections to the public sewers or defects causing I/I are found the program would require that the defects be removed or repaired within a specified time. After the repairs are made, the building owner would have to certify that the repairs were made and that the I/I sources have been eliminated.

9.7 Developer Offset Programs

A developer offset program could be used by the municipalities to reduce I/I from public and private sources. The County has an existing policy that includes reductions in I/I at a ratio of 3:1. The concept is based on any additional sewage generated from new residential, commercial or industrial developments would have to be offset by a reduction in I/I from the existing public and private sewers and properties. A specified quantity of I/I reduction based on additional sewage flow would be required. The developer would be required to provide the list of I/I sources to be removed, the estimated quantity of I/I that would be removed, a schedule for I/I rehabilitation, and a method for post-rehabilitation verification.

9.8 Educational Programs

Educational programs could be implemented by the municipalities to inform the public about the negative impacts of I/I on the operation and maintenance of the sewer system and wastewater treatment plants. It would be more cost-effective and environmentally sound to reduce I/I and implement an ongoing maintenance program of the public and private sewers than to deal with the problems of increasing I/I.

Some of the negative impacts associated with the current I/I, and the certainty of increased I/I if the sewers are not properly maintained, include increased potential for basement backups and overflows from manholes into the streets and receiving waters; increased cost for operation, maintenance, and energy for pump station operation; requirement to increase the hydraulic capacity of the sewers and pump stations; ability of the treatment plants to effectively treat the sewage and comply with their permit conditions for effluent quality; costs associated with treating more clean water; costs associated with plant expansion, if feasible; and compliance with SPDES permit conditions for influent flow and nitrogen removal.

Some elements of a public education program might include the following:

- Public Outreach Meetings,
- Public Access Radio and TV spots,
- Newspaper Articles and Press Releases,
- Informational Flyers,
- School
- Web Site Discussions,
- Social Media Discussions.

A comprehensive public education program might include all of these elements, and others that are appropriate for the individual municipalities.

9.9 Local Law Changes

Some municipalities have existing laws or codes that do not allow for excessive I/I or do not allow any type of private inflow into the public sewers. Depending on the success of reducing I/I through other measures, it may be necessary for the municipalities to enhance existing laws or implement new laws or codes that require the building owners to reduce or eliminate all I/I sources. Municipalities should also consider adopting a user-fee program similar to those instituted in other municipalities.

10.0 RECOMMENDATIONS

Based on the findings of the flow monitoring program, all 11 municipalities that discharge wastewater into the Long Island Sound sewer districts exceed the flow limit specified in the Environmental Facilities Sewer Act. A substantial amount of the flow from each municipality is due to excessive I/I, which has a negative impact on both the collection systems and the wastewater treatment plants. Some of these impacts include the following:

- Reduction in conveyance capacity of the existing sewers, which impacts the available capacity for new development.
- Increased potential for sewage backups into basements.
- Increased potential for overflows from manholes into the streets and receiving waters.
- Increased operation and maintenance cost at the New Rochelle Sanitary Sewer Overflow Facilities.
- Increased energy cost and equipment maintenance at the pump stations.
- Increased potential for overflows at the pump stations.
- Reduced ability of the WWTPs to achieve 85% reduction in TSS and CBOD due to dilution of the raw sewage.
- Increase in nitrogen load at the WWTPs, possibly causing SPDES permit violations for nitrogen discharge.
- Hydraulic overload at the WWTPs, which also increases the potential for SPDES permit violations for flow rate and various treatment parameters.
- Increased costs for WWTP expansion and operating costs.
- Increased energy usage at the WWTPs.

The overall flow reduction strategy would include the following sequential steps for each municipality as shown in the attached Proposed Schedule, Figure 10-1:

- ***Municipality Negotiations:*** It is recommended that Westchester County enter into negotiations with the 11 municipalities to get concurrence from each municipality to develop a program to address the excessive I/I in their sewer systems.

- ***Evaluation Program Development:*** Each municipality will develop municipality specific scope of the Evaluation Program which will entail flow metering, flow isolation, smoke testing, CCTV inspection, lateral inspection, house to house inspections and analysis of field data collected to identify a remedial program to reduce infiltration/inflow within each municipality. The Evaluation Program developed by each municipality should be submitted to Westchester County and NYSDEC for review.

- ***Evaluation Program Implementation:*** Each municipality will implement the Evaluation Program. Prepare a report for submittal to Westchester County and NYSDEC which identifies the necessary repairs, develop a construction cost estimate for the Program and outline the design and construction schedule for implementation.

Following the submittal of the Evaluation Program Report by the 11 municipalities, which will outline the extent, cost and schedule of the rehabilitation programs, Westchester County and NYSDEC will meet to review and discuss the reports and either accept the programs and associated schedules, or request modifications and/or clarifications. Final acceptance of all 11 programs and the associated schedules will be conveyed to the municipalities by Westchester County and NYSDEC by August 1, 2017.

The Evaluation Program and Implementation Schedule should include the following:

1. **Evaluation Program Scope** - the specific locations in the collection system to be targeted for evaluation, the evaluation methodologies to be utilized, the manner in which public and private I/I will be addressed and any proposed parallel programs should all be detailed.

2. **Implementation schedule for the entire program –** the schedule for the entire I/I reduction program should be shown in as much detail as is feasible. The schedule should include, at a minimum, evaluation and quantification of excessive I/I, rehabilitation design, construction, post-rehabilitation verification, and any other parallel programs such as public education, local law changes, and other programs proposed by the municipality.

3. **Schedule for sewer rehabilitation construction –** each municipality should prepare a detailed schedule showing the anticipated start, duration, and completion of the rehabilitation construction. Individual phases of the program should be shown to the extent possible.

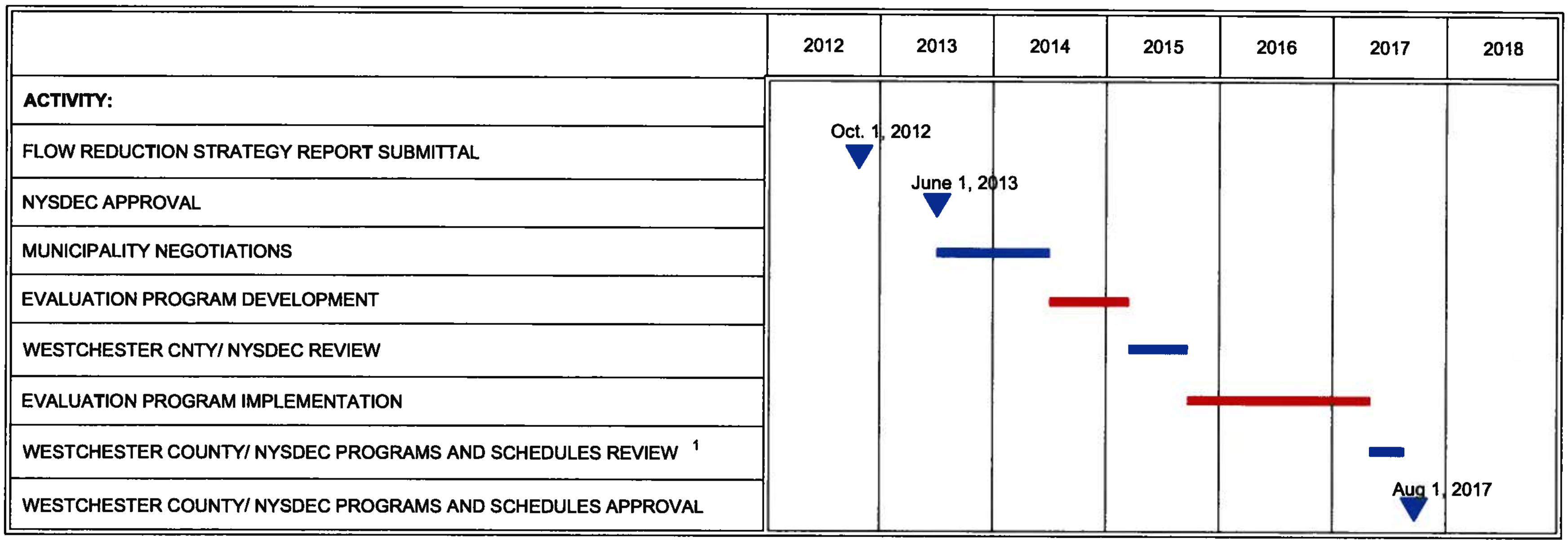
4. **Methods to be used for post-rehabilitation verification –** the Program Outline should include specific steps that each municipality will use to verify and certify that the excessive I/I has been reduced and that the municipality is in compliance with the Environmental Facilities Sewer Act.

WESTCHESTER COUNTY
DEPT. OF PUBLIC WORKS & TRANSPORTATION
DEPT. OF ENVIRONMENTAL FACILITIES

LONG ISLAND SOUND SEWER DISTRICTS
FLOW REDUCTION STRATEGY

FIGURE 10-1

PROPOSED SCHEDULE



G:\SavinAutocad\Shay\WestCountyLongIslndSewerFlowRedStrategy_10-1_rev.4.dwg

KEY

- WESTCHESTER COUNTY / NYSDEC ACTION (blue)
- MUNICIPALITY ACTION (red)

REV. 4 5/14/2013

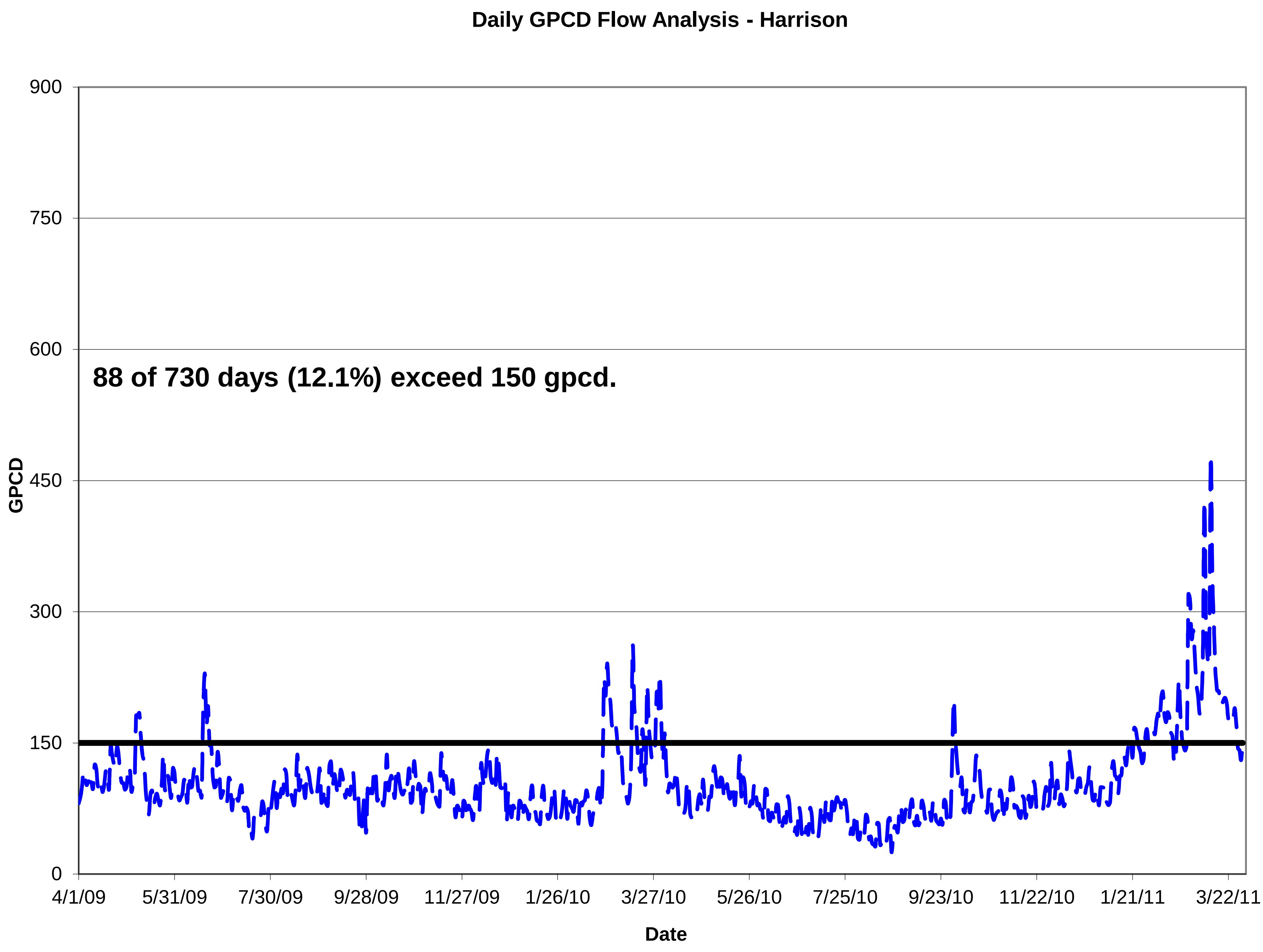
1. WESTCHESTER COUNTY AND NYSDEC WILL REVIEW AND DISCUSS ALL THE PROPOSED PROGRAMS AND IMPLEMENTATION SCHEDULES WHICH ARE SUBMITTED BY THE MUNICIPALITIES AND APPROVE EACH ONE, AS MODIFIED BY THE REVIEW PROCESS, BY AUGUST 1, 2017.

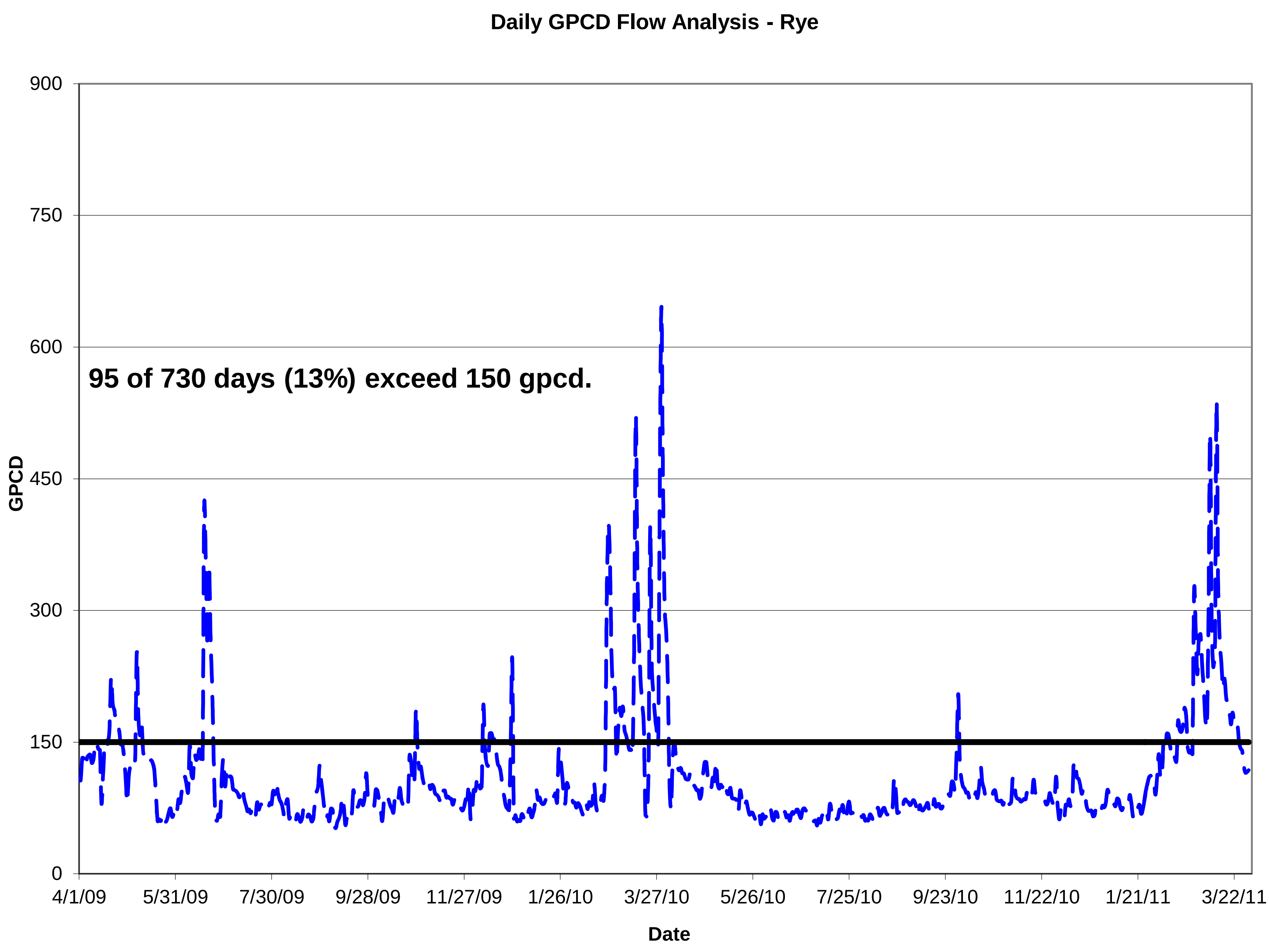
Savin Engineers, P.C.

APPENDICES

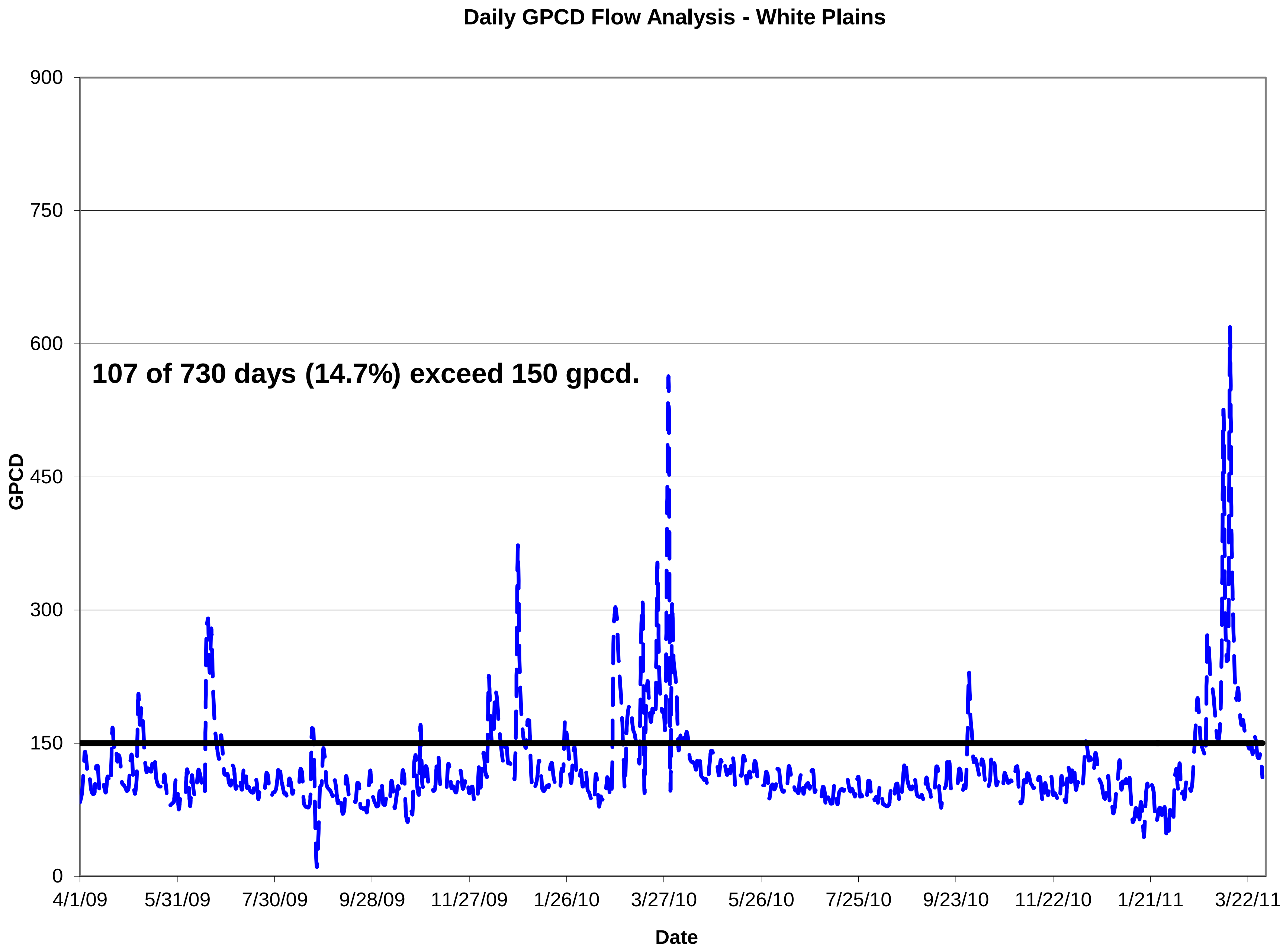
APPENDIX A

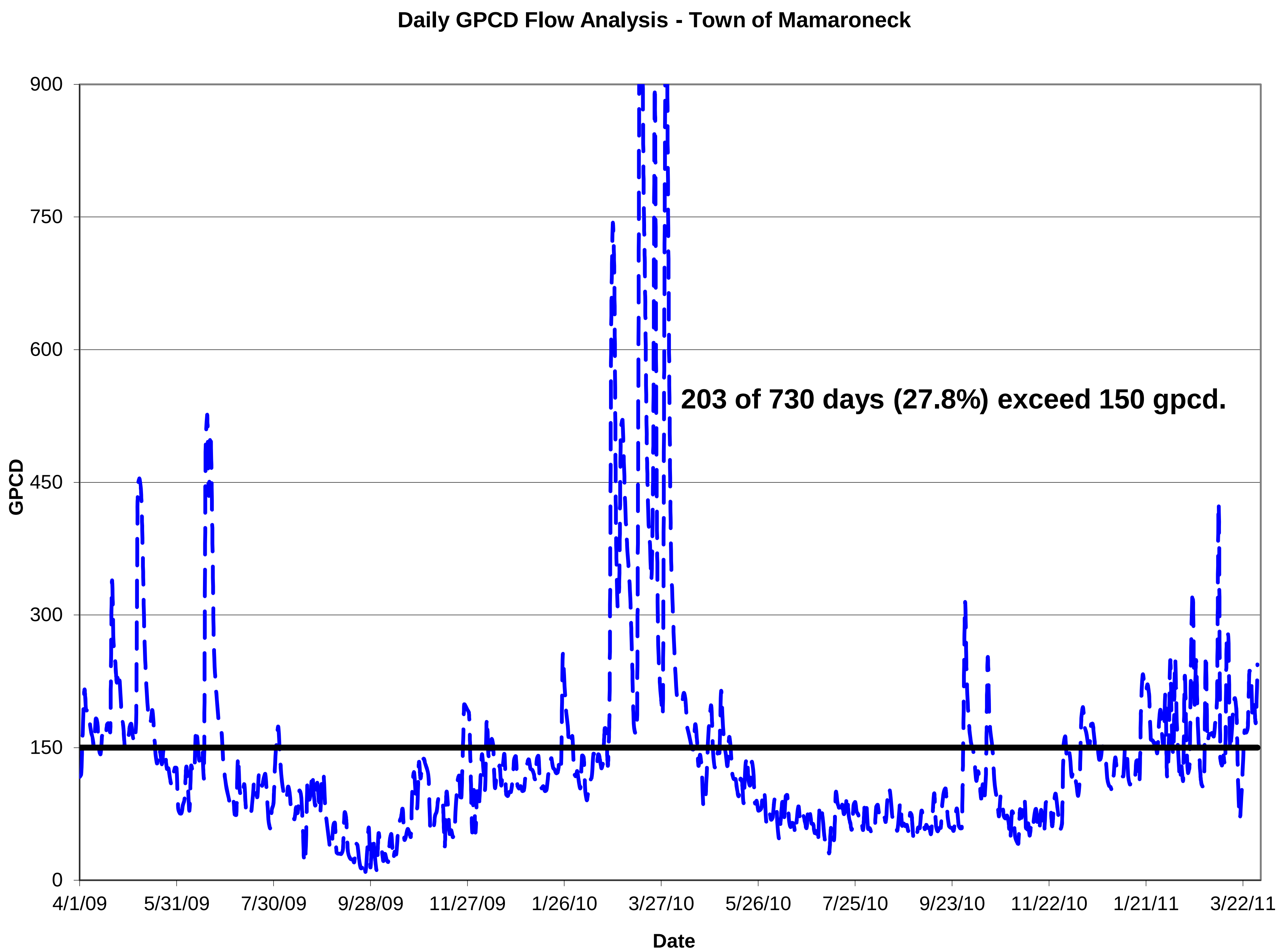
Daily Per Capita Hydrographs for LIS Municipalities


Daily GPCD Flow Analysis - Harrison
88 of 730 days (12.1%) exceed 150 gpcd.
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date

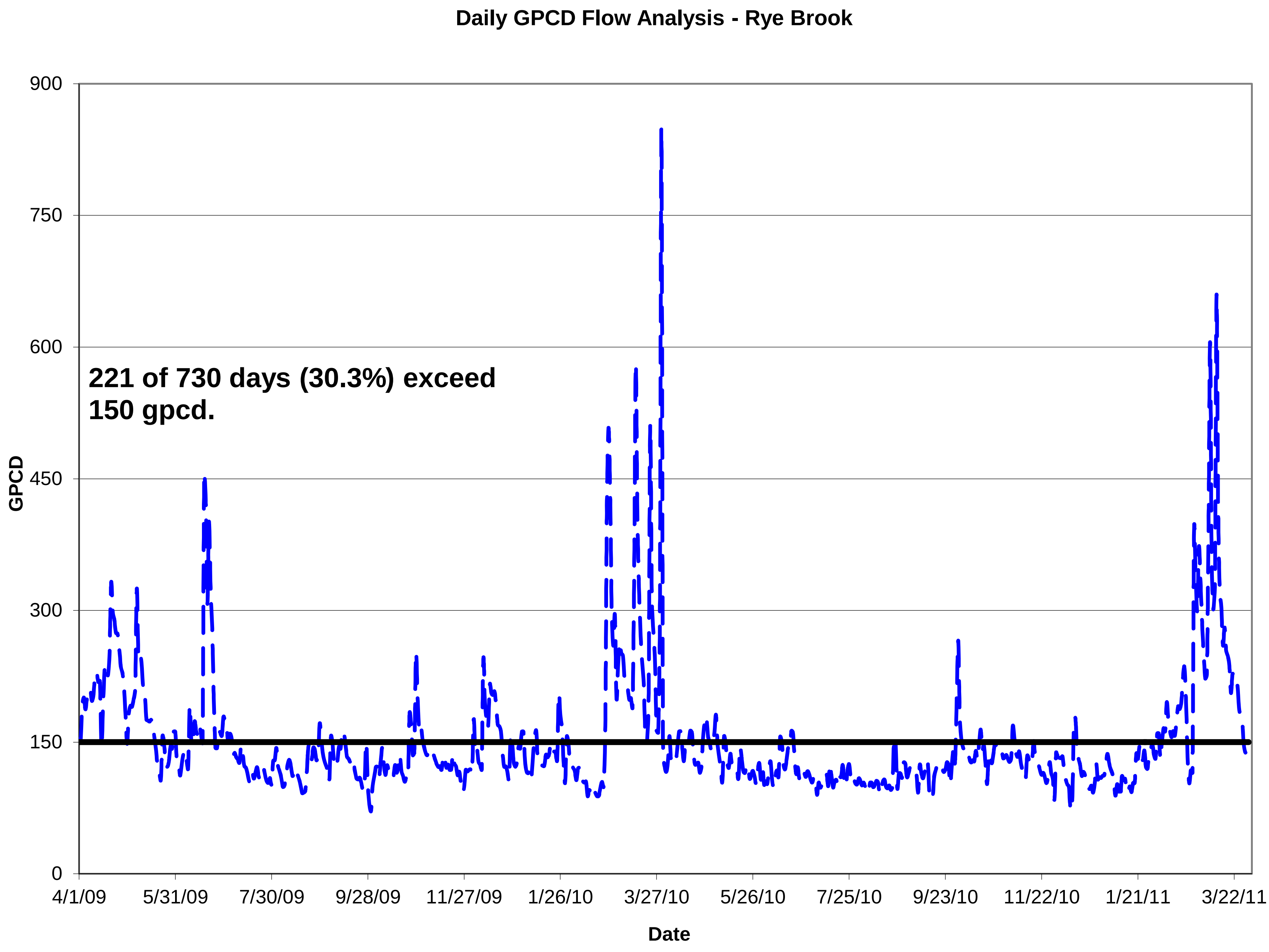


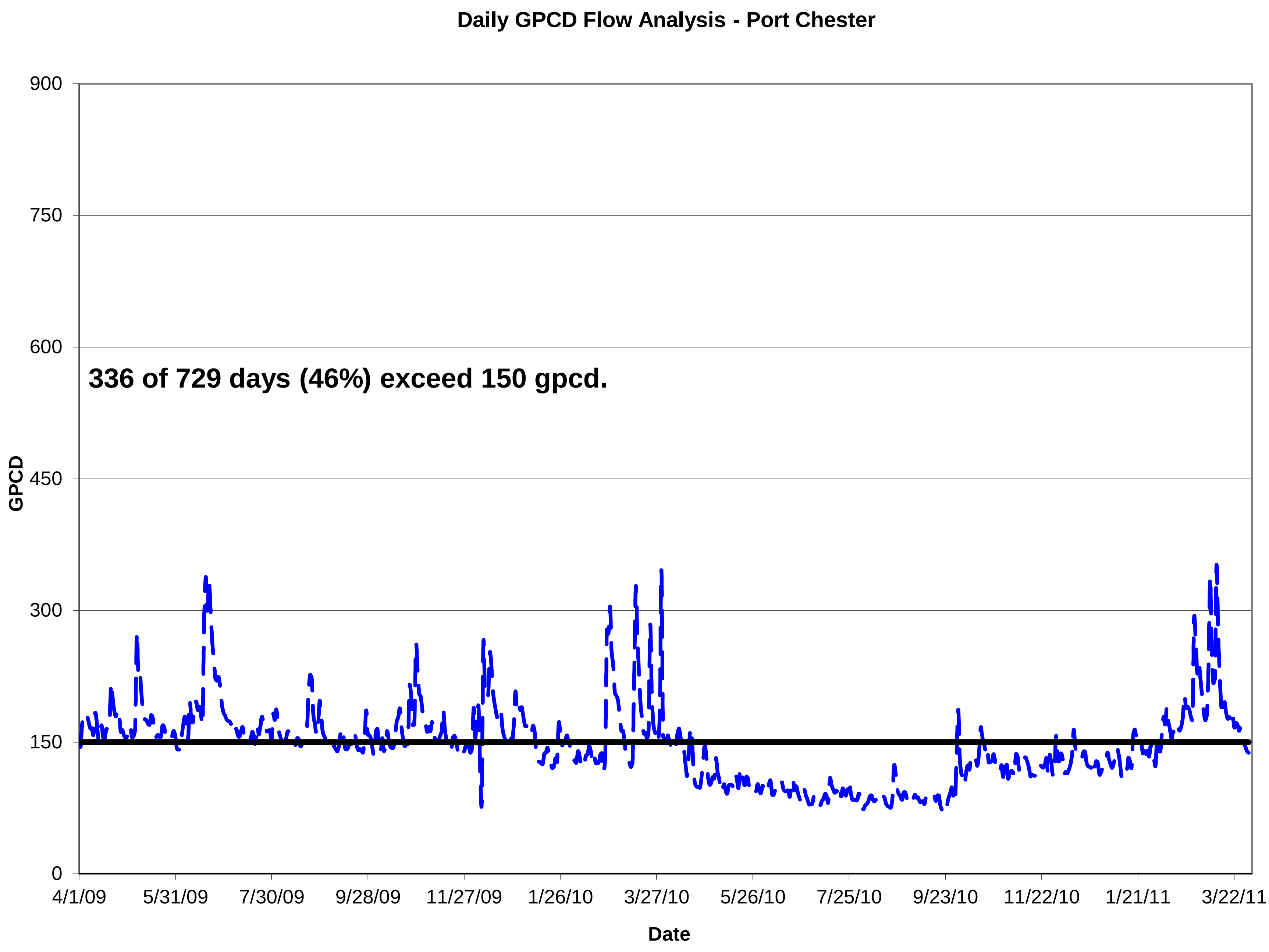
Daily GPCD Flow Analysis - Rye
95 of 730 days (13%) exceed 150 gpcd.
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date


Daily GPCD Flow Analysis - White Plains
107 of 730 days (14.7%) exceed 150 gpcd.
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date

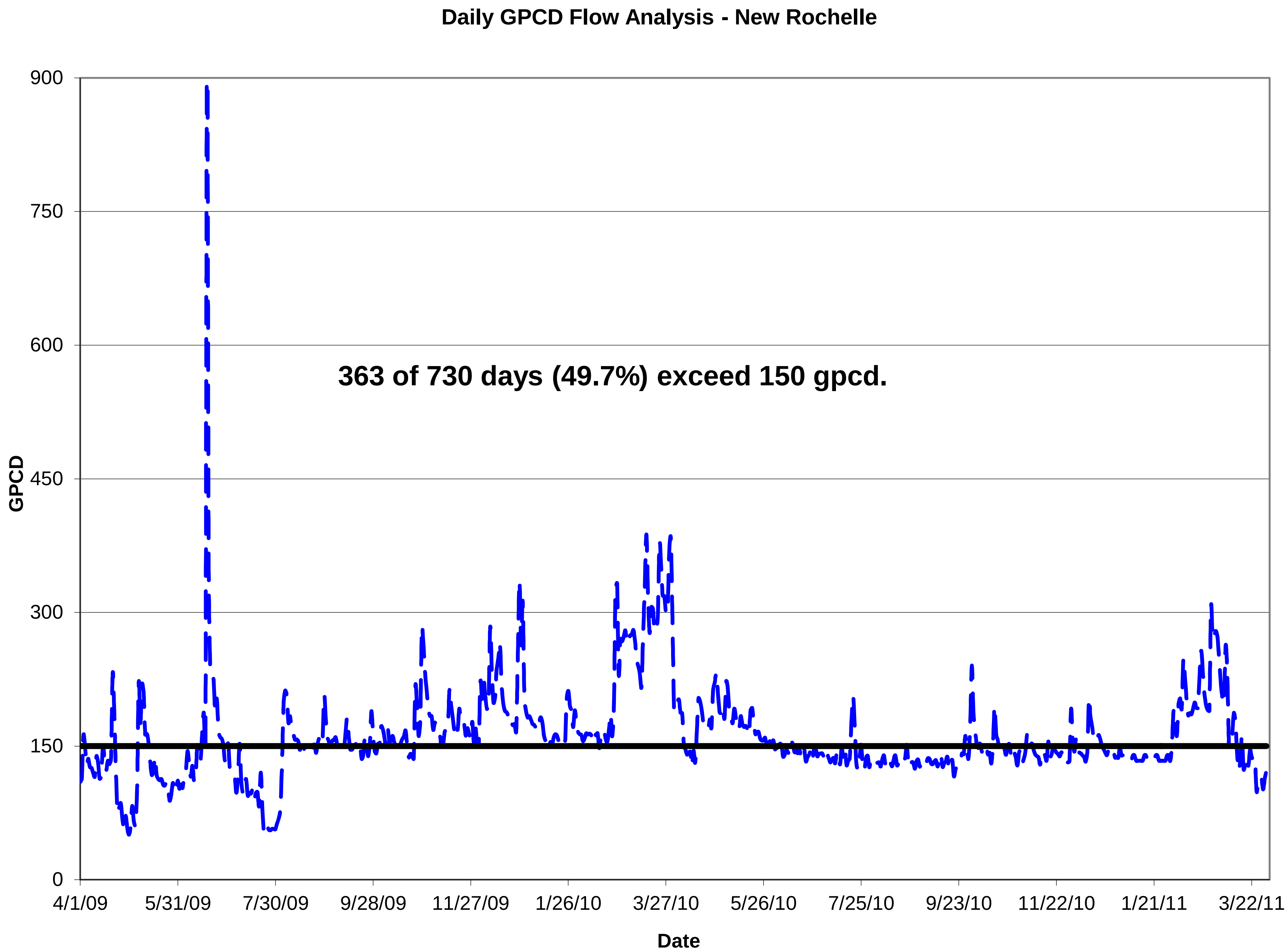


Daily GPCD Flow Analysis - Town of Mamaroneck
GPCD
900
750
600
450
300
150
0
203 of 730 days (27.8%) exceed 150 gpcd.
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date

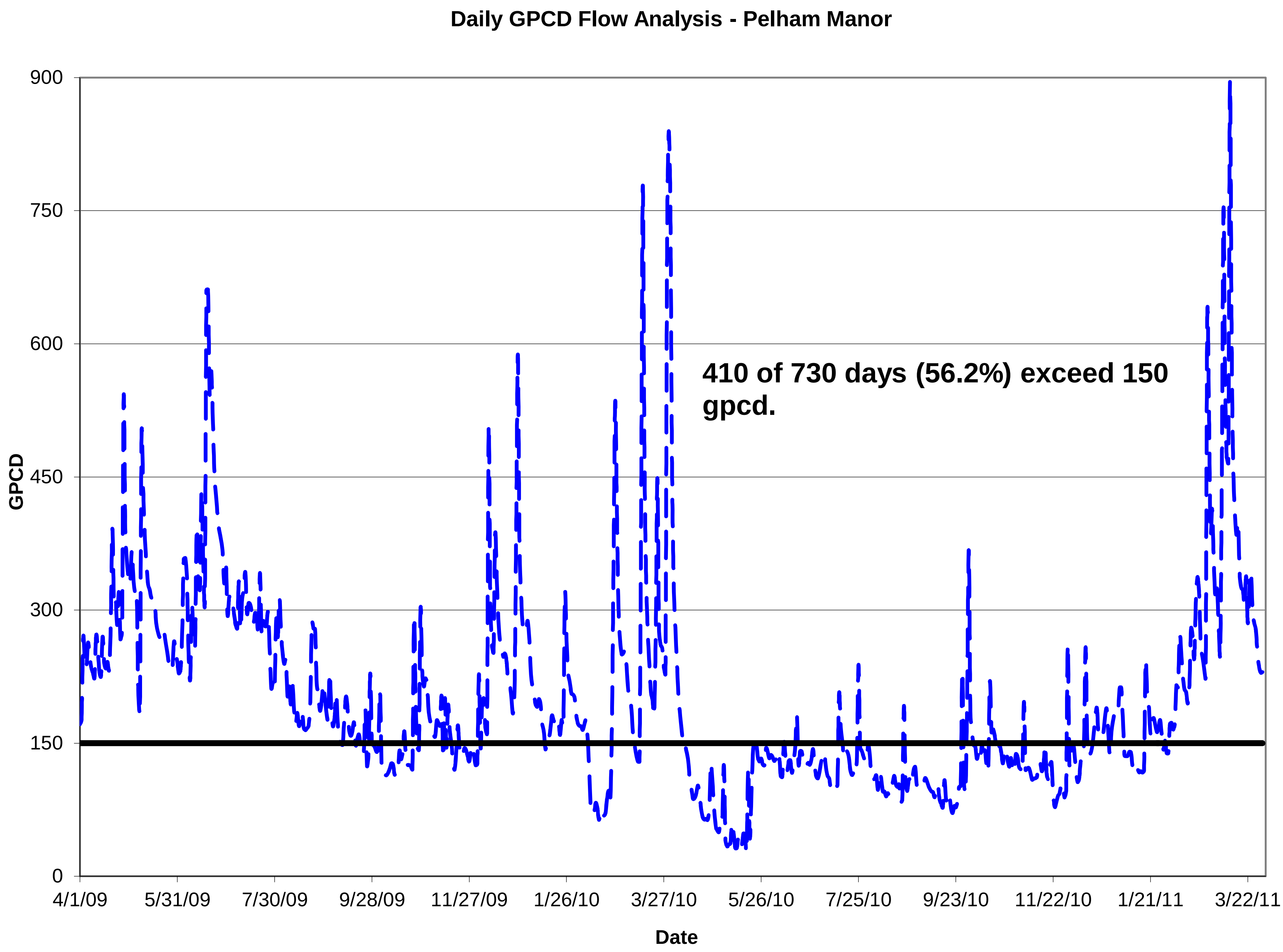

Daily GPCD Flow Analysis - Rye Brook
221 of 730 days (30.3%) exceed
150 gpcd.
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date



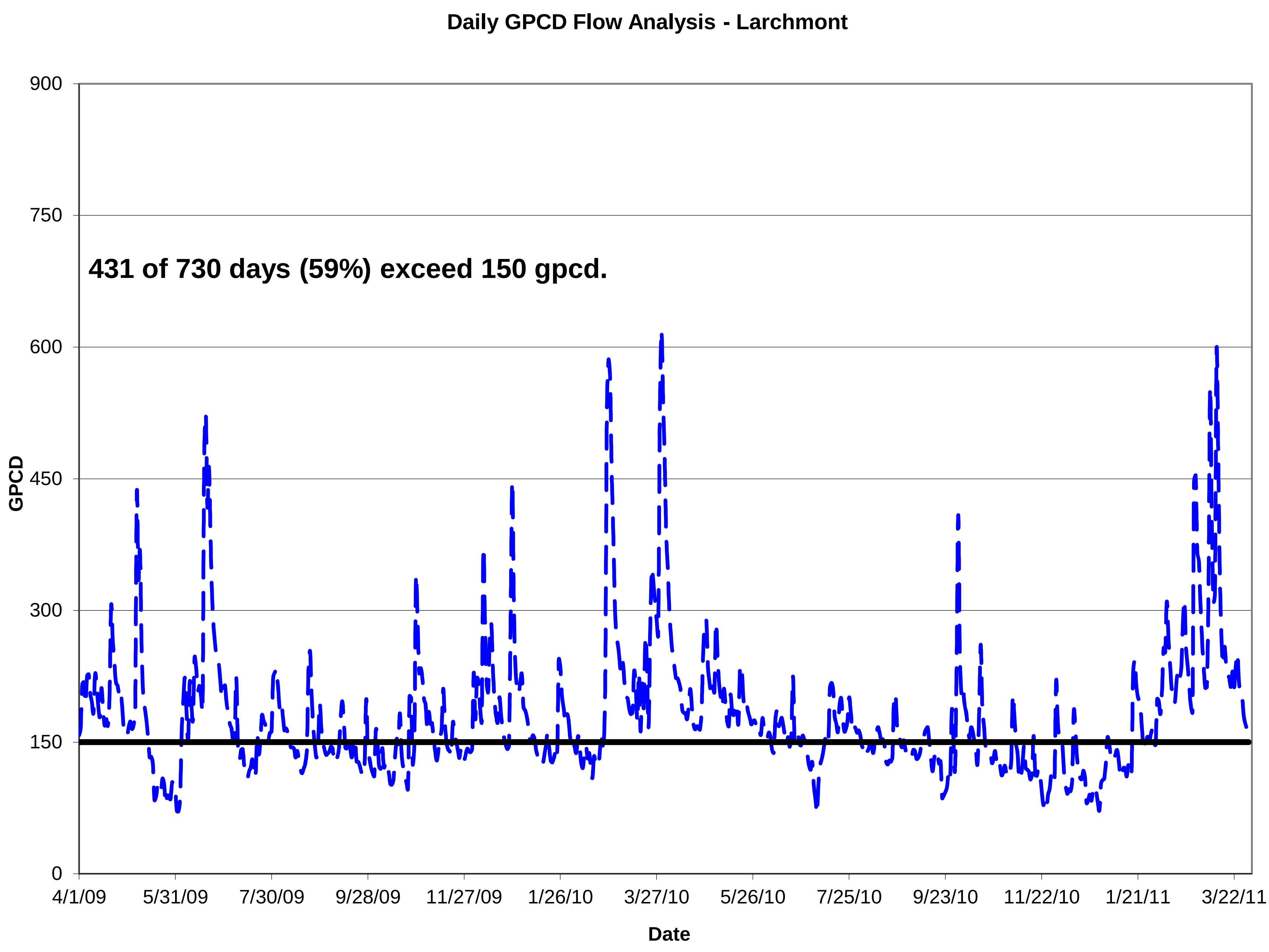
Daily GPCD Flow Analysis - Port Chester
336 of 729 days (46%) exceed 150 gpcd.
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date

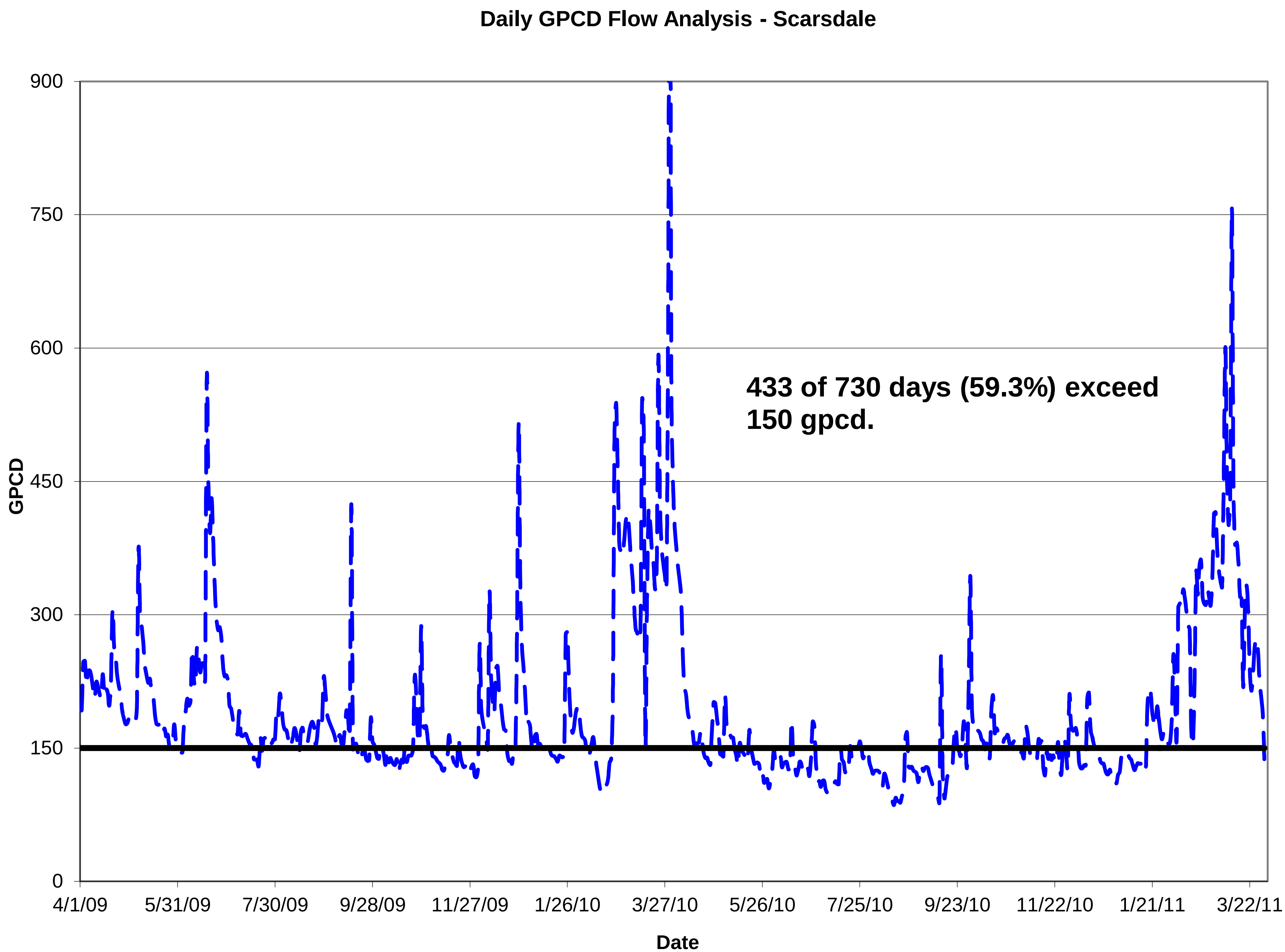


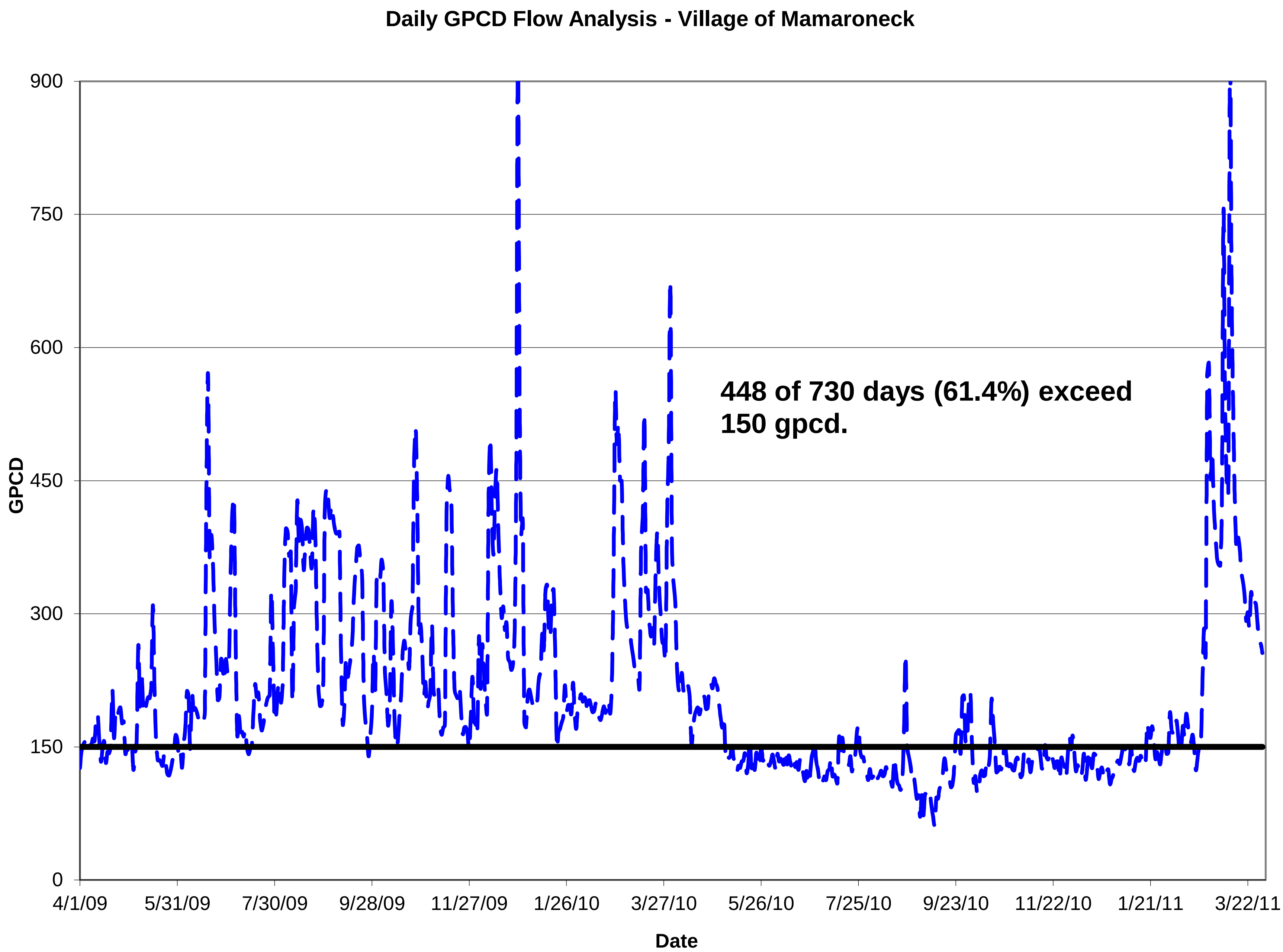
Daily GPCD Flow Analysis - New Rochelle
363 of 730 days (49.7%) exceed 150 gpcd.
GPCD
0
150
300
450
600
750
900
Date
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11



Daily GPCD Flow Analysis - Pelham Manor
GPCD
900
750
600
450
300
150
0
410 of 730 days (56.2%) exceed 150 gpcd.
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date


Daily GPCD Flow Analysis - Larchmont
431 of 730 days (59%) exceed 150 gpcd.
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date

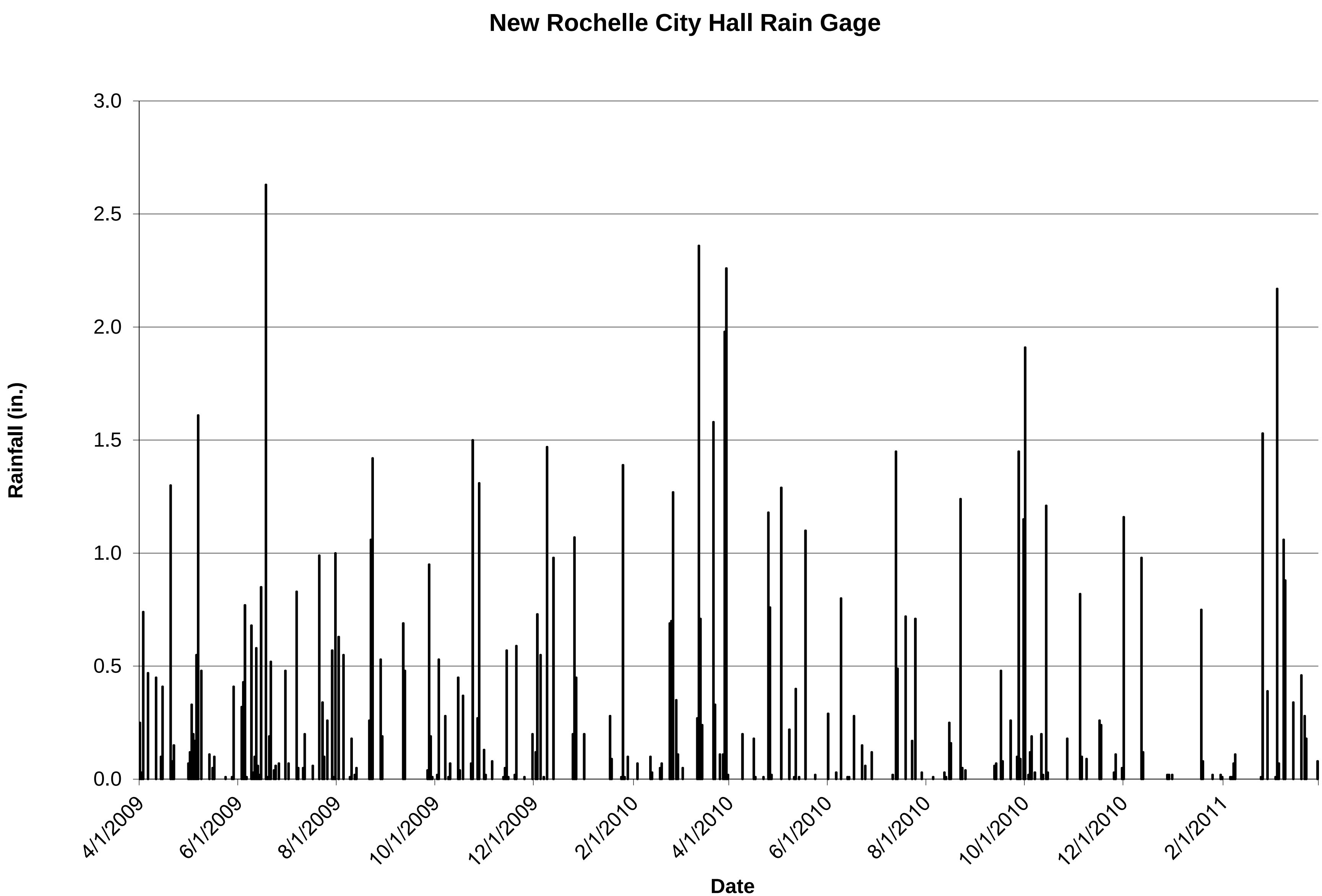

Daily GPCD Flow Analysis - Scarsdale
GPCD
900
750
600
450
300
150
0
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date
433 of 730 days (59.3%) exceed 150 gpcd.

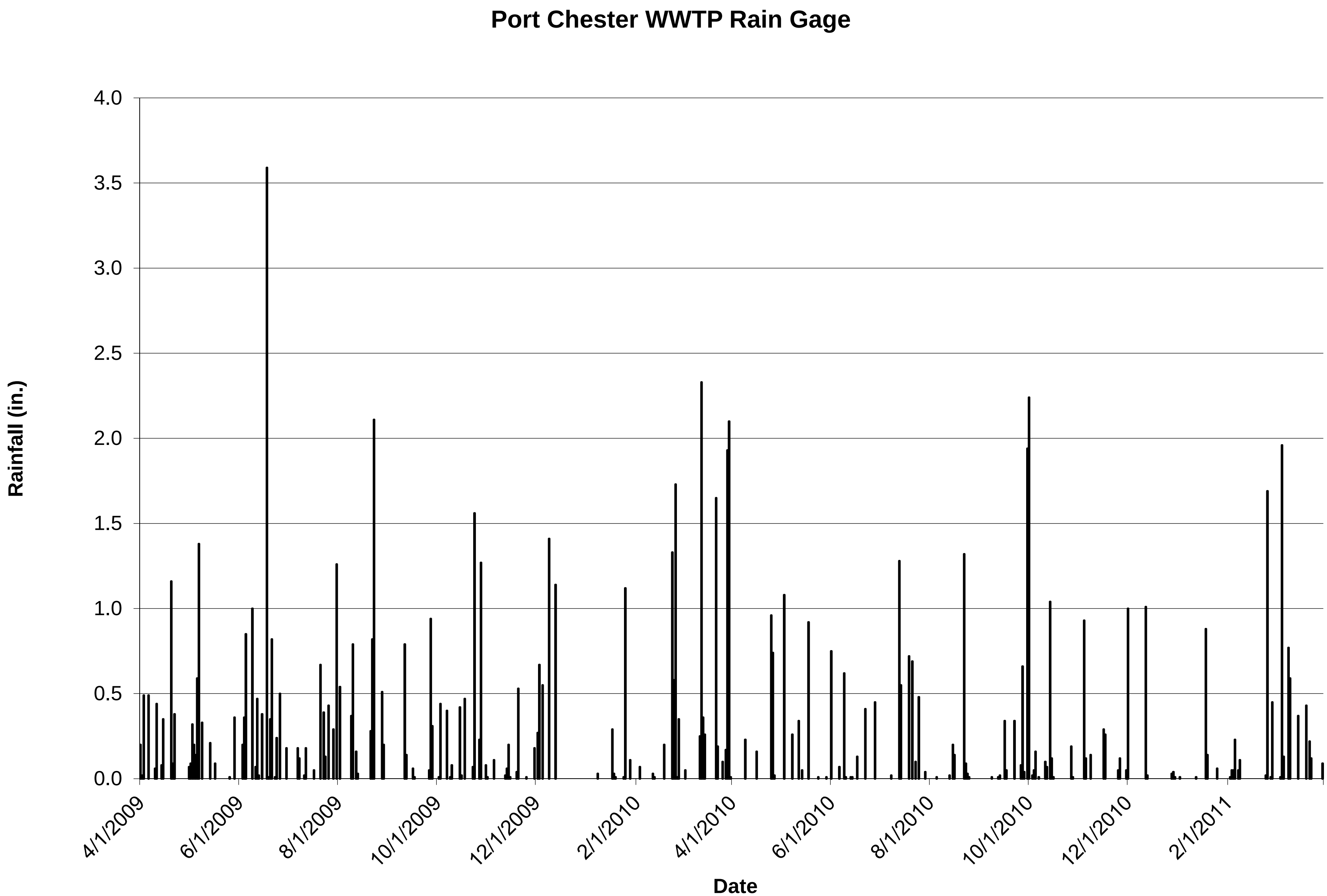


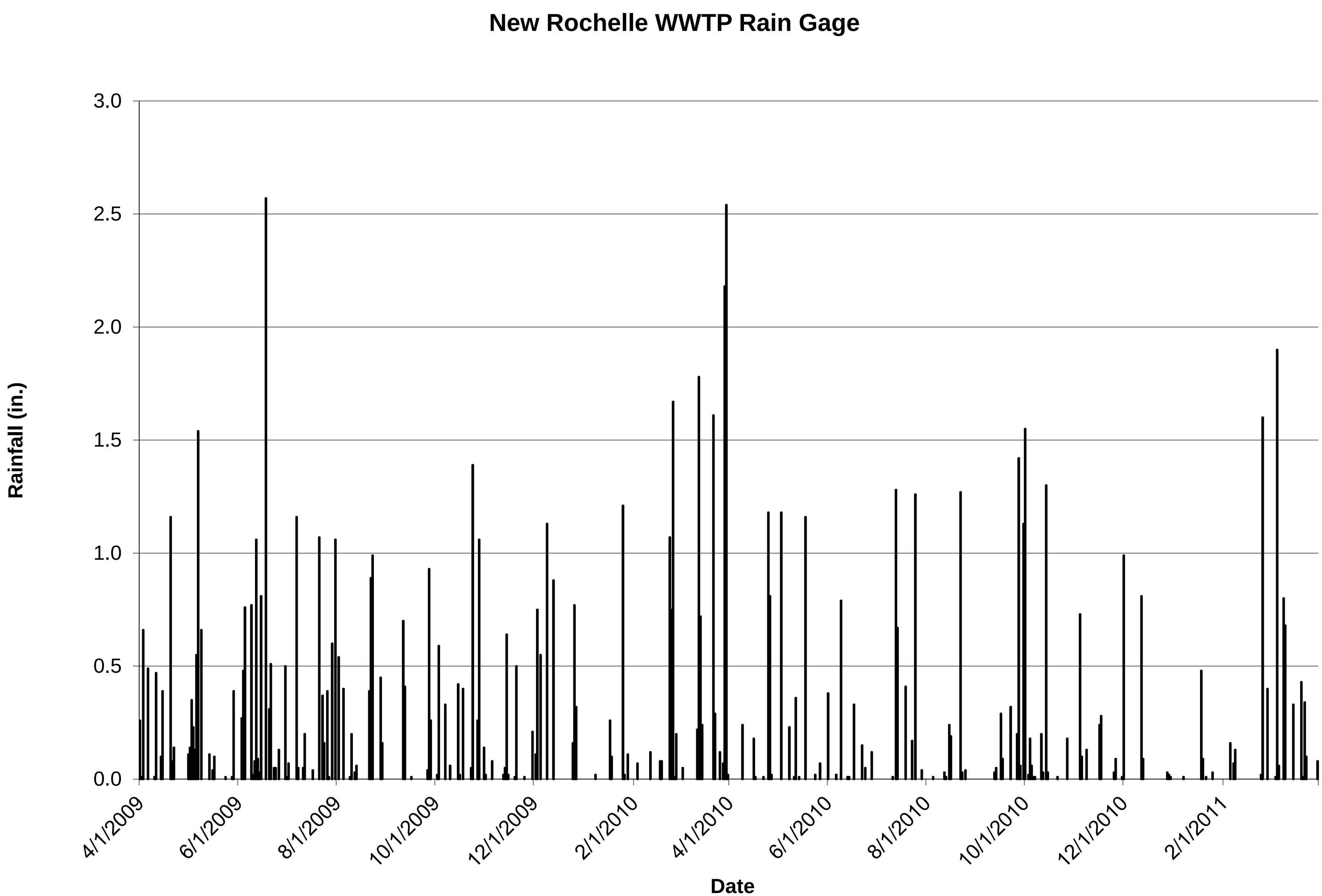
Daily GPCD Flow Analysis - Village of Mamaroneck
GPCD
900
750
600
450
300
150
0
448 of 730 days (61.4%) exceed 150 gpcd.
4/1/09
5/31/09
7/30/09
9/28/09
11/27/09
1/26/10
3/27/10
5/26/10
7/25/10
9/23/10
11/22/10
1/21/11
3/22/11
Date

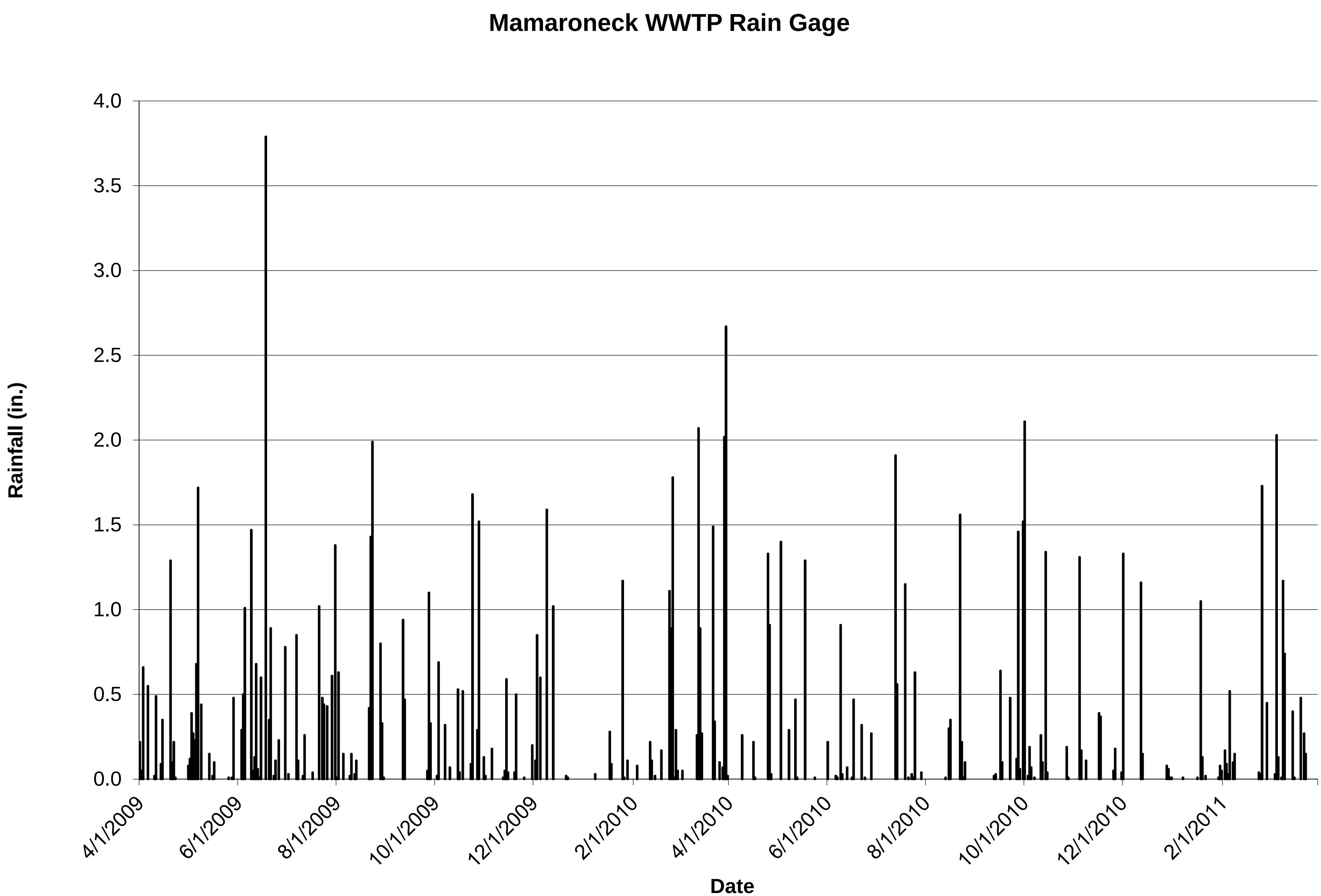
APPENDIX B

Rainfall Graphs

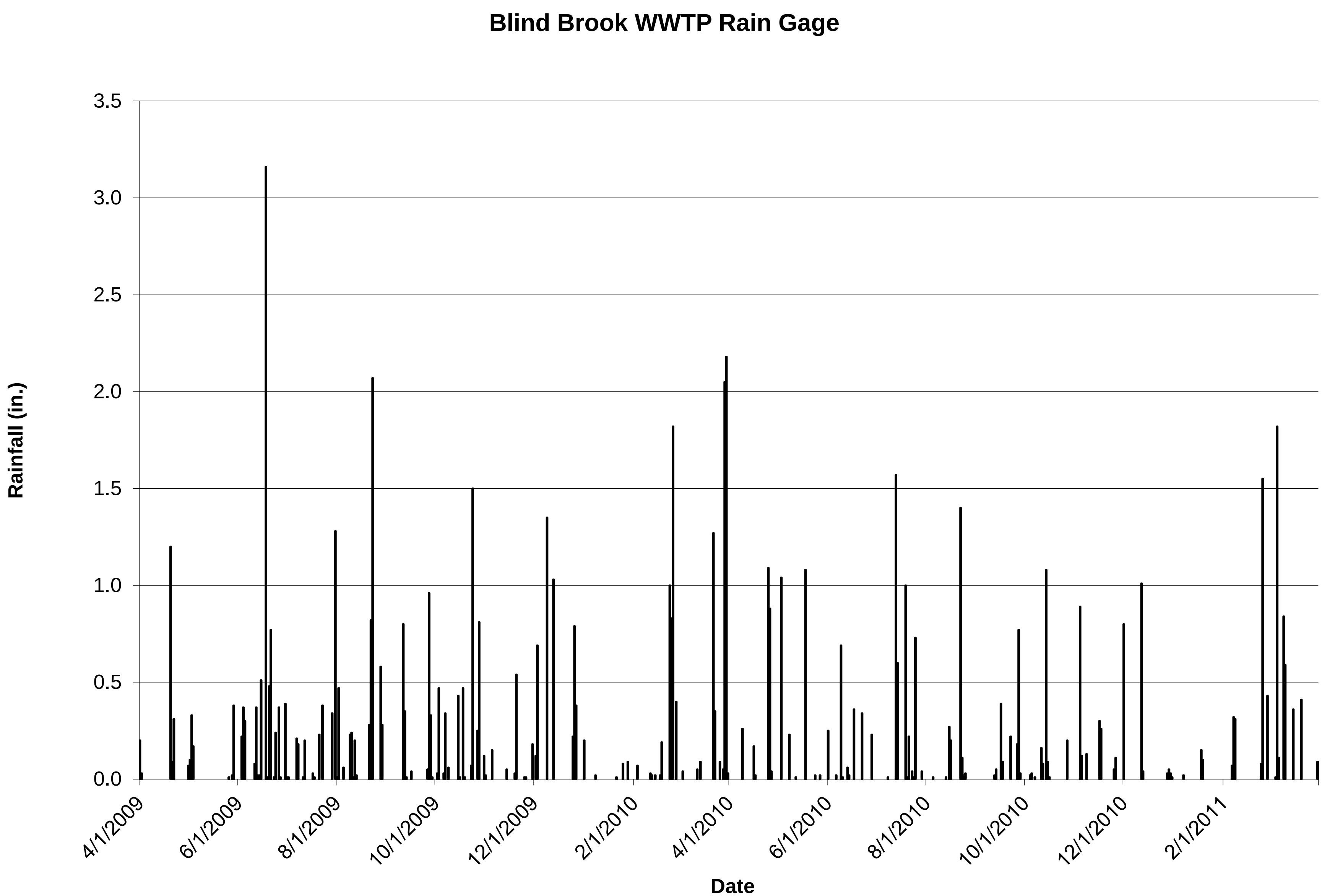

New Rochelle City Hall Rain Gage
Rainfall (in.)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date

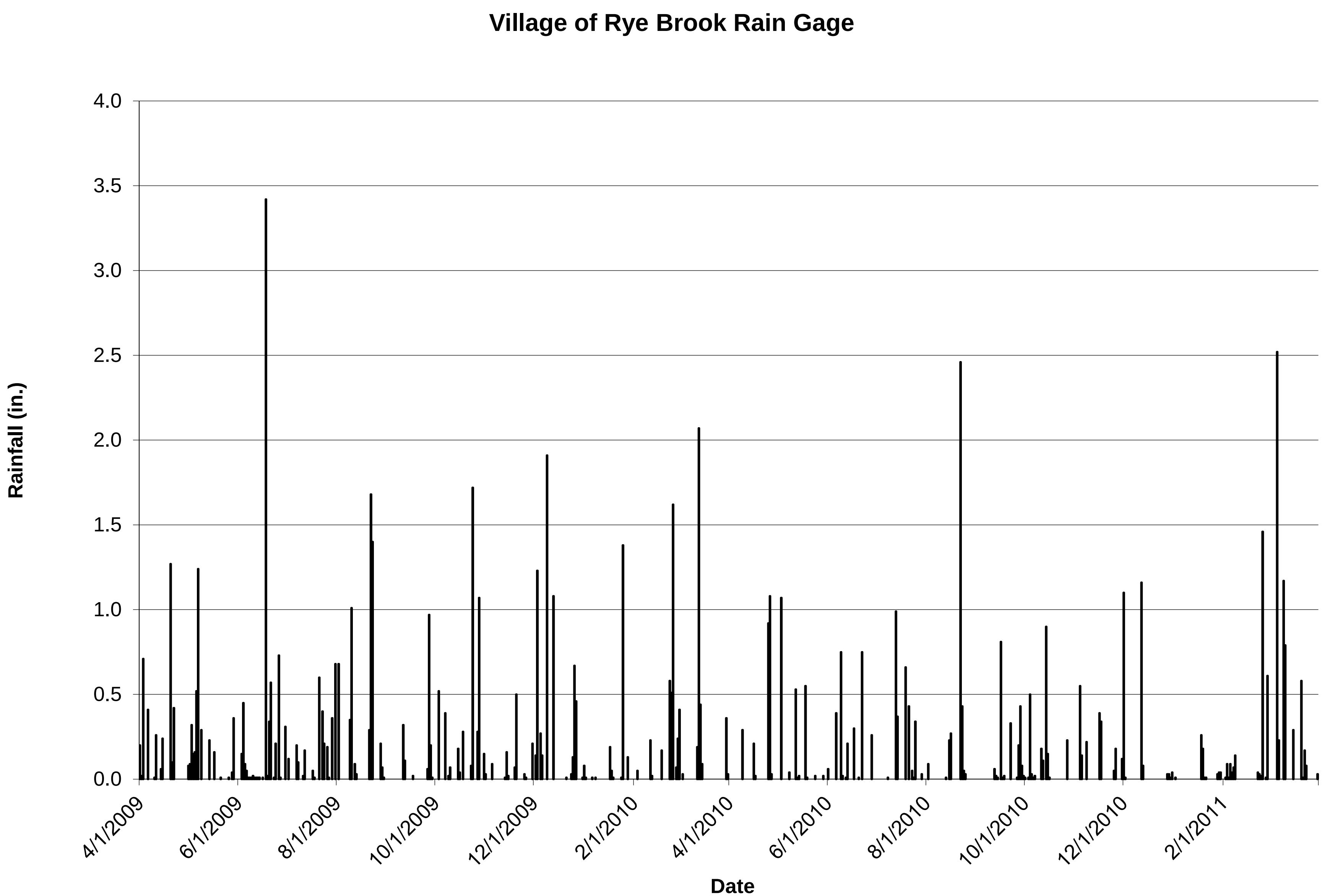

Port Chester WWTP Rain Gage
Rainfall (in.)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date


New Rochelle WWTP Rain Gage
Rainfall (in.)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date

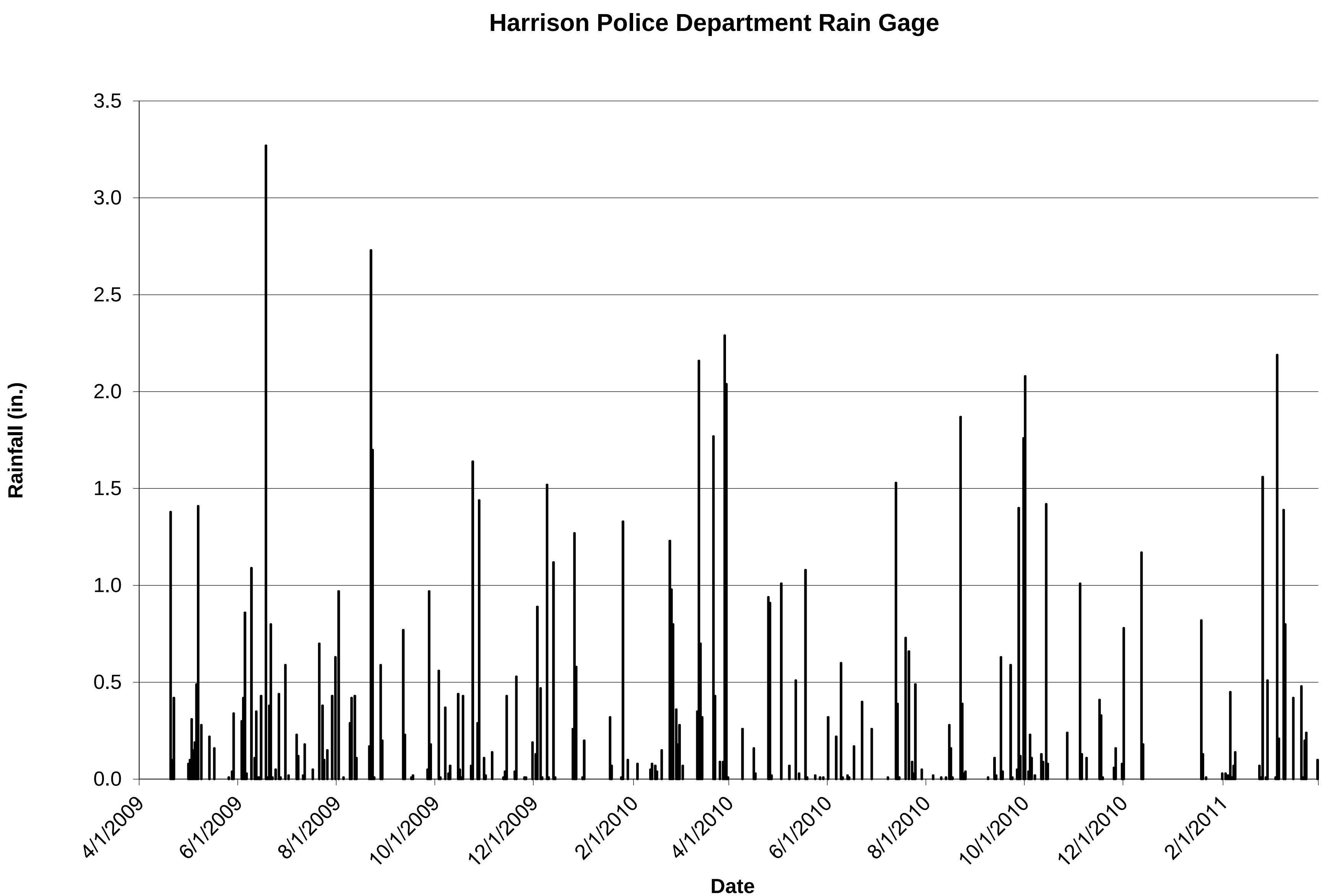


Mamaroneck WWTP Rain Gage
Rainfall (in.)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date

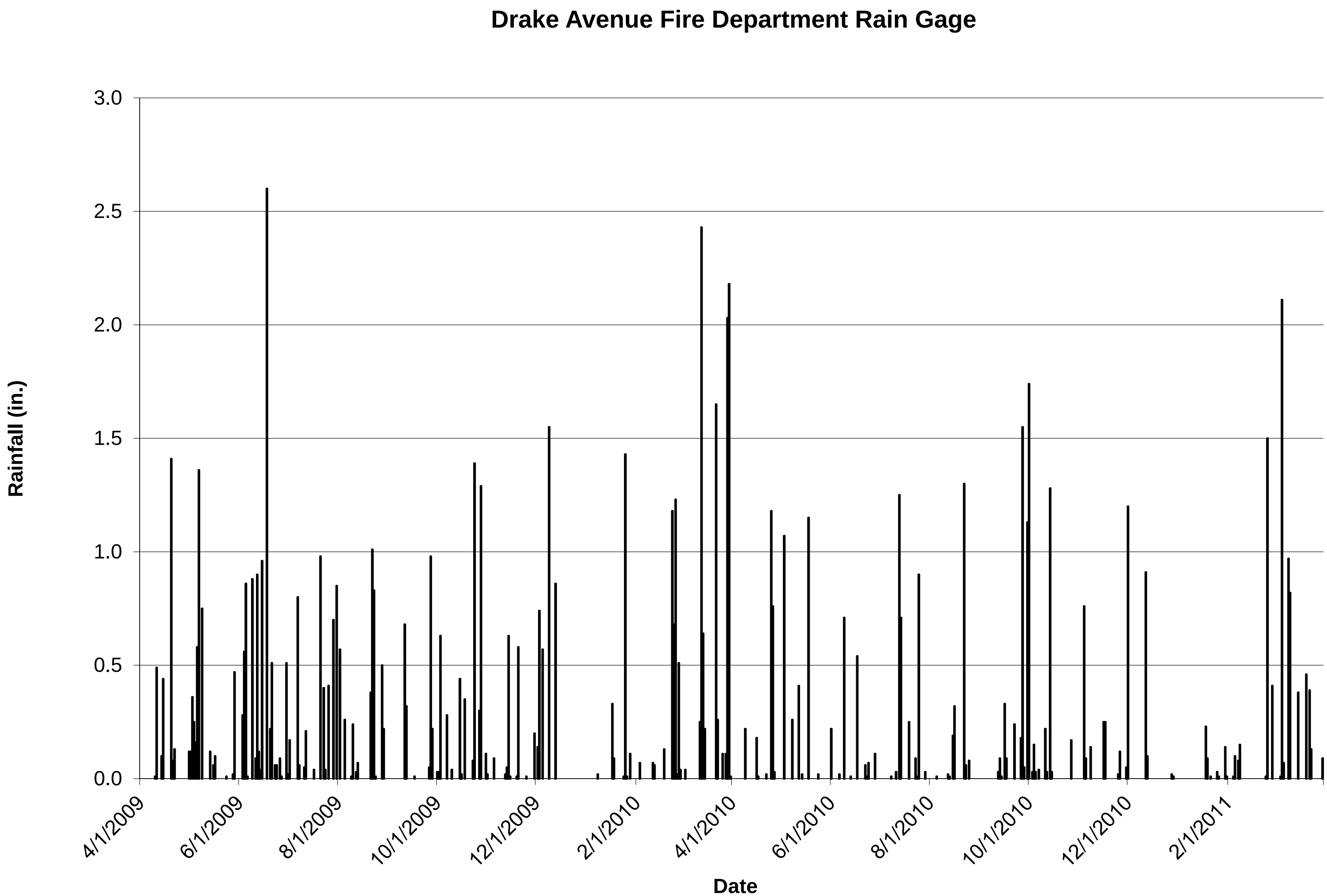

Blind Brook WWTP Rain Gage
Rainfall (in.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date

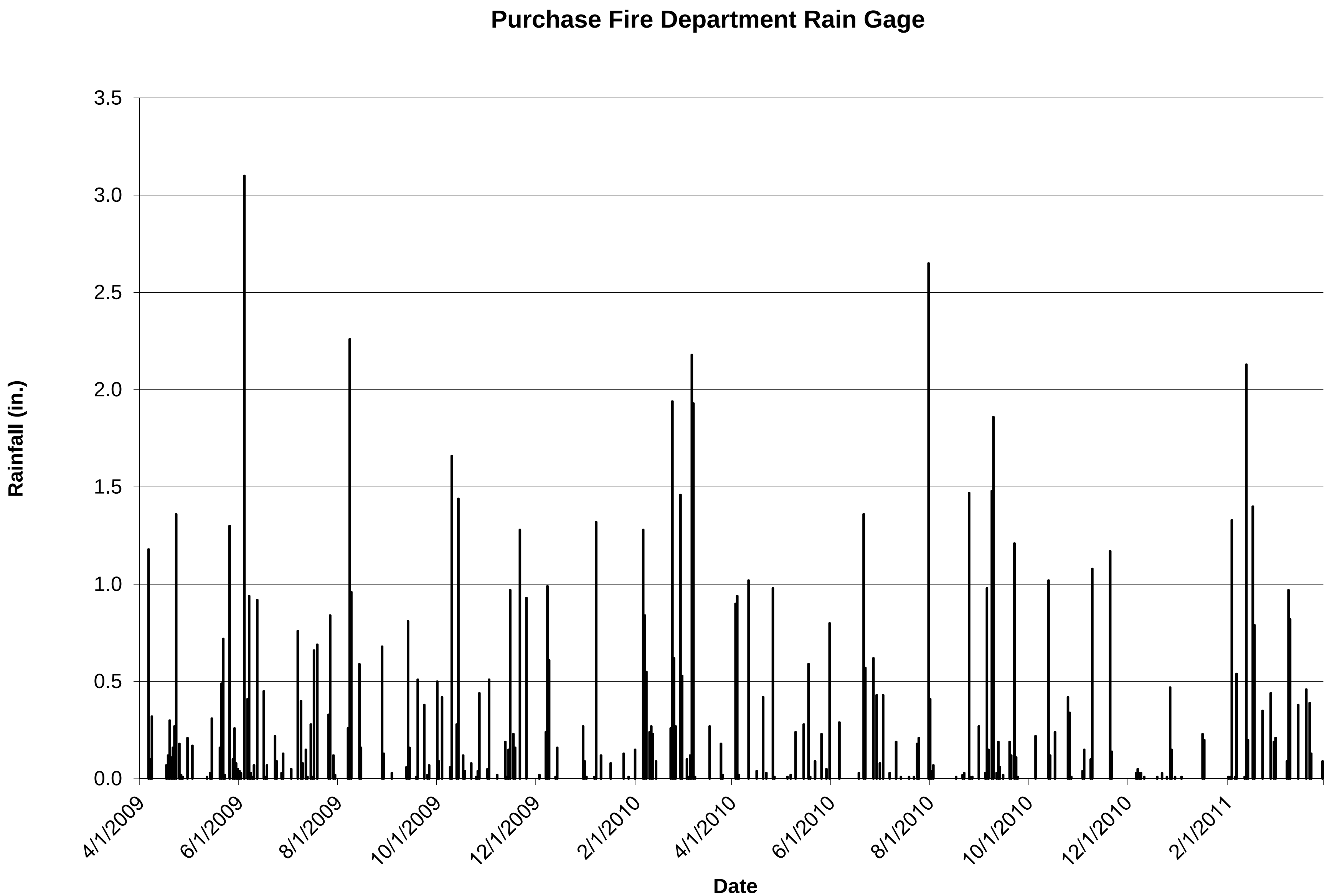


Village of Rye Brook Rain Gage
Rainfall (in.)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date

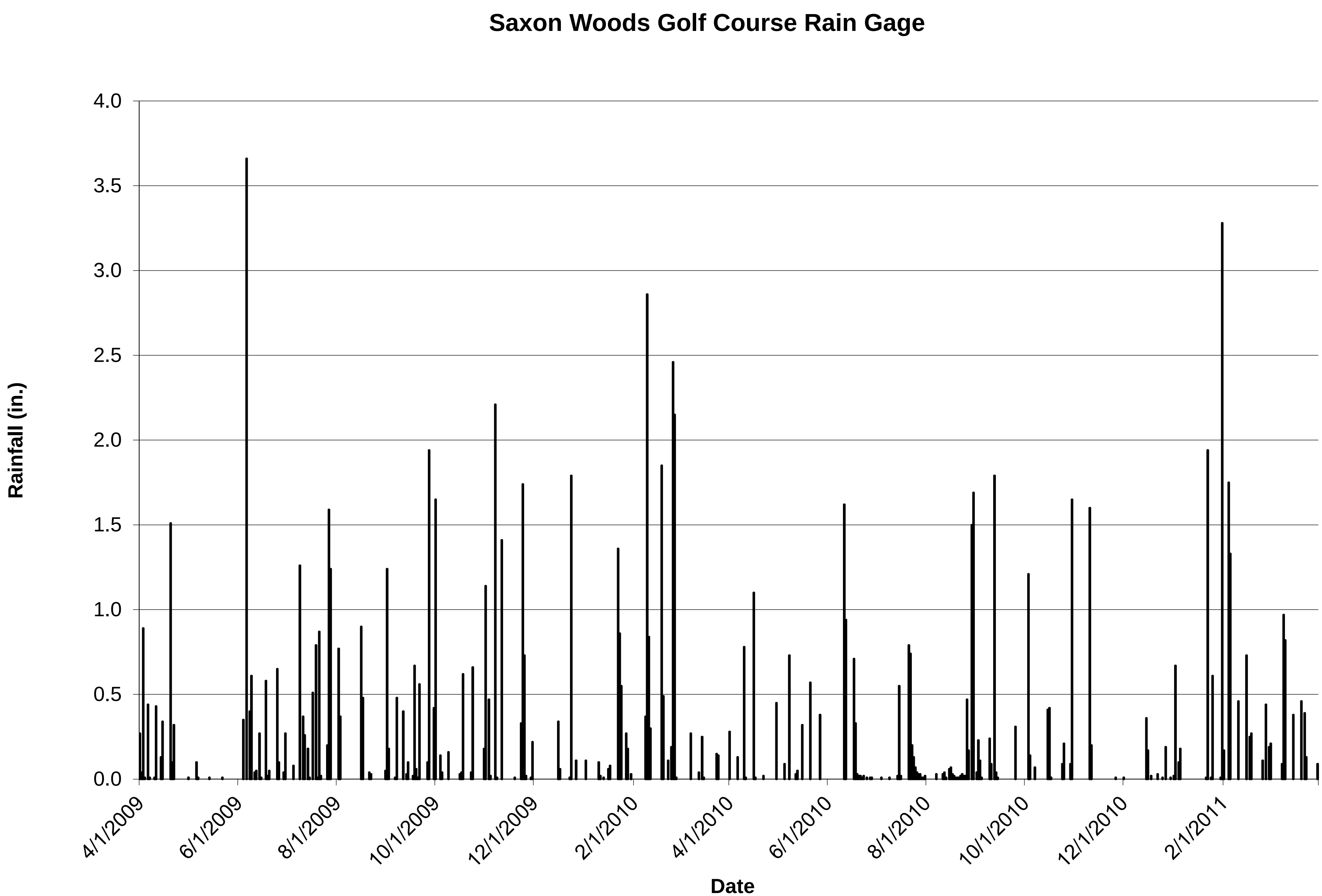


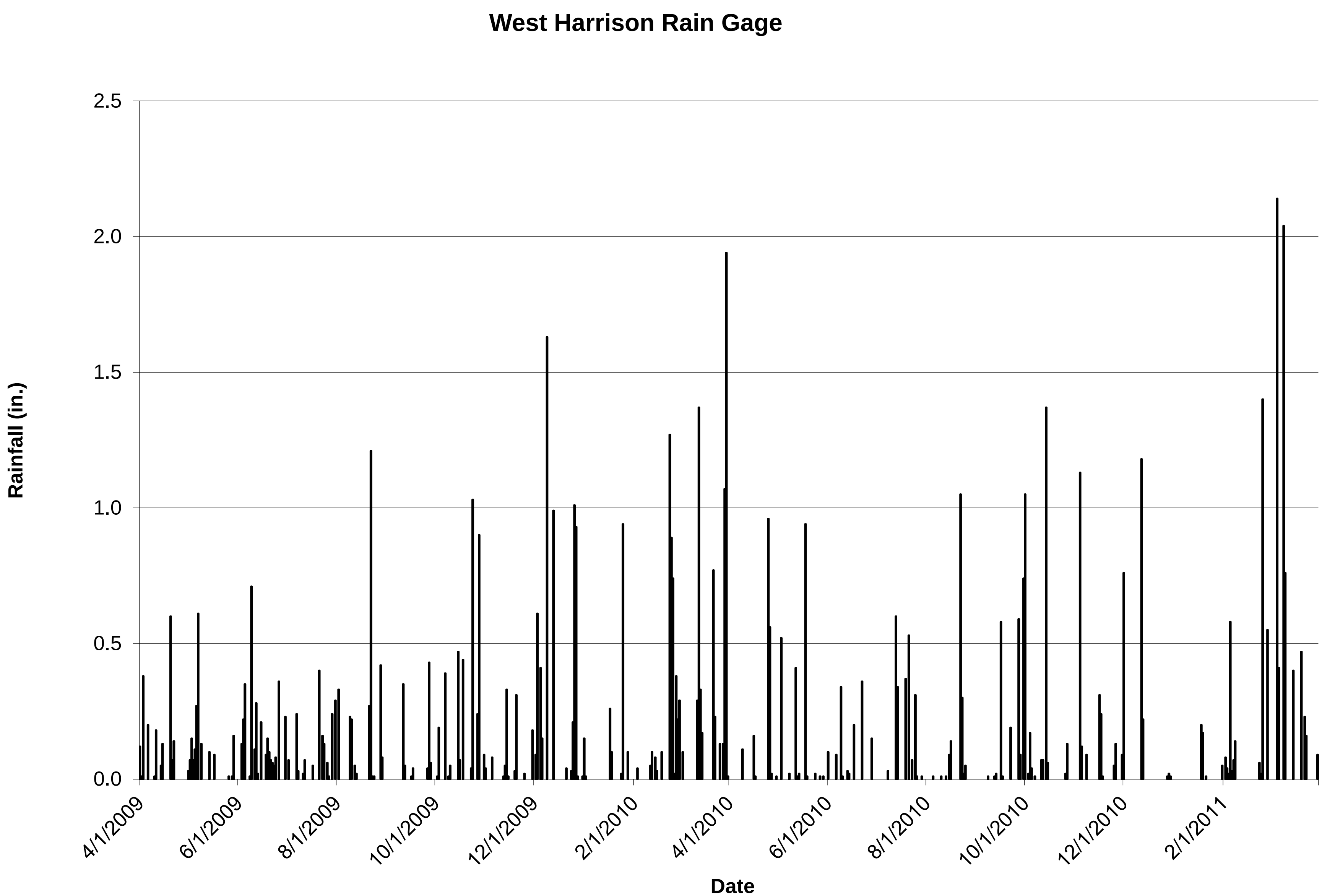
Harrison Police Department Rain Gage
Rainfall (in.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date

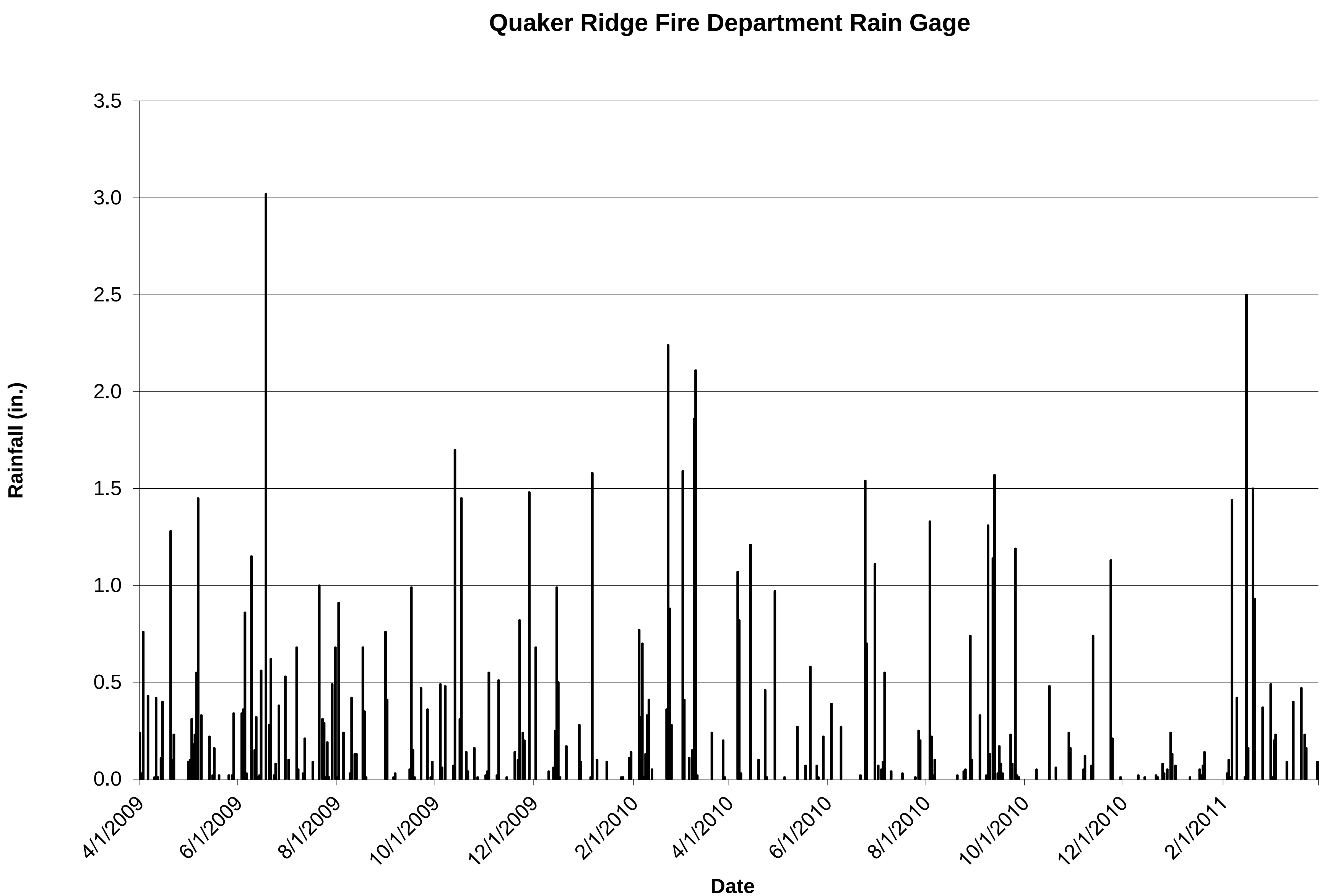

Drake Avenue Fire Department Rain Gage
Rainfall (in.)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date



Purchase Fire Department Rain Gage
Rainfall (in.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date


Saxon Woods Golf Course Rain Gage
Rainfall (in.)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date


West Harrison Rain Gage
Rainfall (in.)
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date



Quaker Ridge Fire Department Rain Gage
Rainfall (in.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4/1/2009
6/1/2009
8/1/2009
10/1/2009
12/1/2009
2/1/2010
4/1/2010
6/1/2010
8/1/2010
10/1/2010
12/1/2010
2/1/2011
Date