Environmental
Protection

INFOWORKS
Citywide Recalibration Report

Updates to and Recalibration of October 2007 NYC Landside Models

The City of New York
Department of Environmental Protection
Bureau of Wastewater Treatment

June 2012

Table of Contents

List of Tables

List of Figures

Glossary

BMP: Best Management Practice

CPK: Central Park

CSO: Combined Sewer Overflow

Design Dry Weather Flow (DDWF): The flow basis for design of New York City wastewater treatment plants. In general, the plants have been designed to treat 1.5 times this value to full secondary treatment standards and 2.0 times this value, through at least primary settling and disinfection, during stormwater events.

Dry Weather Flow (DWF): Hydraulic flow conditions within a combined sewer system resulting from one or more of the following: flows of domestic sewage, ground water infiltration, commercial and industrial wastewaters, and any other non-precipitation event related flows (e.g., tidal infiltration under certain circumstances).

EWR: Newark International Airport

JFK: John F. Kennedy Interntional Airport

LGA: Laguardia International Airport

Long-Term Control Plan (LTCP): A document developed by CSO communities to describe existing waterway conditions and various CSO abatement technologies that will be used to control overflows.

New York City Department of Environmental Protection (DEP): New York City agency responsible for addressing the environmental needs of the City's residents in areas including water, wastewater, air, noise and hazmat.

Real-Time Control (RTC): A system of data gathering instrumentation used in conjunction with control components such as dams, gates and pumps to maximize storage in the existing sewer system.

SCADA: Supervisory Control and Data Acquisition

SFR: Single-family residence

State Pollutant Discharge Elimination System (SPDES): Under New York State law the program for the control of wastewater and stormwater discharges in accordance with the Clean Water Act is known as the State Pollutant Discharge Elimination System (SPDES) and is broader in scope than that required by the Clean Water Act in that it controls point source discharges to groundwaters as well as surface waters.

Wastewater Planning Users Group (WaPUG): a consortium of firms and institutions in the United Kingdom that developed "action" levels, or acceptable performance criteria for urban drainage models titled Code of Practice for the Hydraulic Modeling of Sewer Systems, www.wapug.org.uk

Wastewater Treatment Plant (WWTP): A facility that receives wastewaters (and sometimes runoff) from domestic and/or industrial sources, and by a combination of physical, chemical, and biological processes reduces (treats) the wastewaters to less harmful byproducts; known by the acronyms, STP (sewage treatment plant), POTW (publicly owned treatment works), WPCP (water pollution control plant) and WWTP.

Waterbody/Watershed (WB/WS) Facility Plan: A predecessor document to the LTCP defined by the Administrative Consent Order. A waterbody/watershed facility plan supports the long-term CSO control planning process by describing the status of implementation of the nine USEPA recommended elements of an LTCP .

Wet Weather Capacity (WWC): The nominal maximum flow rate as sewer may be able to carry, or a WWTP may be able to accept, during wet weather conditions. This capacity could vary somewhat based on the actual conditions that exist at a particular time.

NYC Plant Acronyms

26W - 26th Ward Wastewater Treatment Plant
BB - Bowery Bay Wastewater Treatment Plant
CI - Coney Island Wastewater Treatment Plant
HP - Hunts Point Wastewater Treatment Plant
JA - Jamaica Wastewater Treatment Plant
NC - Newtown Creek Wastewater Treatment Plant
NR - North River Wastewater Treatment Plant
OH - Owls Head Wastewater Treatment Plant
PR - Port Richmond Wastewater Treatment Plant
RH - Red Hook Wastewater Treatment Plant
RK - Rockaway Wastewater Treatment Plant
TI - Tallman Island Wastewater Treatment Plant
WI - Wards Island Wastewater Treatment Plant

NYC Citywide Watershed Model Recalibration Report

Section 1
Introduction

1.1 Background

During development of Waterbody/Watershed Facility Plans (WWFP) submitted in the late 2000s to the New York State Department of Environmental Conservation (DEC), the commercially available hydrologic/hydraulic model InfoWorks (IW) was employed for each wastewater treatment plant (WWTP) service area, as documented in a series of model calibration reports dated October 2007. There were 13 volumes of the report entitled “City-Wide Long Term CSO Control Planning Project, Landside Modeling Report”; each volume developed for an individual WWTP conveyance system. The reports documented the development process and status of the collection/conveyance system models as of October 2007 and presented results showing the goodness of fit between calculated model flows and depths with those measured within the collection system at various times prior to 2007. The model versions employed by the City as documented in these reports were InfoWorks-CS versions 6.5 and 7.0.

The 2007 reports contain an extensive amount of information relative to the collection system and the corresponding model configuration and application. Models allow the best representation of complex real-world systems in a mathematical framework that can be used for planning and design evaluations. As such, they must be updated periodically when additional information becomes available or when system operational procedures are changed. Over time, sewer system models are modified and updated based on new information obtained during various facility planning and design projects. During such projects, it may be necessary to inspect the combined sewers, conduct flow monitoring, compile additional data to refine the understanding of system hydraulics, conduct hydraulic calculations, etc. All of these activities provide information which can and has been used over time to update and improve the IW models discussed herein.

As such, the information that follows in this 2012 report provides a summary of updates made to the models as part of ongoing work efforts by the DEP between 2007 and 2012. It will serve to document the starting point for any collection system modeling used to develop LTCPs between 2011 and 2017, the date for delivery of the final City-Wide LTCP to the DEC. Any additional information compiled will be presented in the LTCP reports providing the basis and benefits achieved from such efforts.

1.2 Model Impervious Cover

The IW models calculate runoff in a hydrology module that is based on hydrology computations originally contained in the United States Environmental Protection Agency’s Storm Water Management Model (EPA SWMM). The model contains two surfaces: pervious and impervious to represent the landcover conditions in an urban watershed (or sewershed). When rainfall is imposed on pervious surfaces, a fraction infiltrates into the soil and this can be characterized using different modeling approaches while the remaining fraction will form overland surface flow (i.e., runoff) that is then routed to the entry point to a storm or combined sewer. Rainfall occurring on an impervious surface would experience small initial loss through ponding on the surface, with the remaining translated to overland runoff that directly flows into the sewer system. The approach followed during the IW modeling documented in the October 2007 reports was to use a Horton infiltration equation to calculate the amount of rainfall that infiltrates into the ground from pervious surfaces. For impervious surfaces all rainfall, except a very small initial amount that ponds, was assumed to create overland flow that would get into the sewer system. For any given area, the portion that was defined as impervious was estimated using available data from the NYCMap street GIS layer plus building footprint layer and an adjustment factor of 10% to account for sidewalks and driveways that were not then available in those GIS layers. Six representative areas around the City were used to generate the 10% adjustment factor for the percent imperviousness (see Figure 1-1 as an example).

As the City started to focus attention on the use of green infrastructure to manage street runoff by either slowing it down prior to entering the combined sewer network or preventing it from entering the network entirely, it became clear that a more detailed evaluation of impervious cover would be essential. In addition, the City realized that it would be important to distinguish, during this evaluation, between impervious surfaces that directly introduce runoff into the sewer system from impervious surfaces that may not contribute runoff to the system. For example, a rooftop with roof drains directly connected to the combined sewers, as required by the NYC Plumbing Code, would be an impervious surface that is directly contributing runoff to the combined sewer system. A road or right-of-way sidewalk would also be directly contributing runoff. However, a sidewalk in a park or cemetery may contribute runoff to the adjacent pervious areas, and thus may not contribute to the combined sewer system. A portion of a sloped roof draining onto a lawn would be another type of impervious surface that may not be directly connected to a combined sewer system.

In 2009 and 2010, DEP invested in the development of high quality satellite measurements of impervious surfaces at a 7.9 ft by 7.9 ft (2.4 meter) pixel level to provide such planning level impervious data. This data as provided by Columbia University Lamont Earth Observatory is described in Section 2.1.2. The main focus of the model recalibration was initiated to refine the IW models with this new impervious cover data. As the recalibration effort was initiated, it was clear that other changes should be made in the models, in comparison to the versions documented in 2007 reports. These additional changes are described further in Section 2.

Representative Area (Example)

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 1-1

1.3 Model Recalibration Strategy

The general approach followed herein was to recalibrate the model in a stepwise fashion with the main emphasis of the calibration being to focus on the hydrology module (runoff) of the model. This portion of the models was most impacted as a result of changes made since October 2007. This module of the model is where the impervious areas were modified. The following steps summarize the approach to model recalibration.

- Site scale calibration (Hydrology) – The first step in the recalibration process was to determine the impervious areas directly connected to the sewer system and assess the runoff coefficients for pervious areas. Flow monitoring data were collected in upland areas of the collection systems, remote from (and hence largely unaffected by) tidal influences and in-system flow regulation as described in Section 3 for use in understanding the runoff characteristics of the impervious surfaces. Phase 1 data was collected in the Fall 2009 and Phase 2 was collected in the Fall 2010. These areas were on the order of 15 to 400 acres in spatial extent. A range of areas with different landuse mixes were selected to support the development of a standardized set of coefficients that can be applied to other unmonitored areas of the city. Therefore, the main focus of this element of the recalibration was to adjust pervious and impervious area runoff coefficients to provide the best fit of the runoff observed at the upland flow monitors.
- Area-wide recalibration (Hydrology and Hydraulics) – The next step in the process was to focus on larger areas of the modeled systems where historical flow metering data was available and which were still un-impacted by tidal backwater conditions and were not subjected to any flow regulation. Where necessary runoff coefficients were further adjusted to provide reasonable simulation of flow measurements made at the downstream end of these larger areas. The calibration process then moved downstream further into the collection system where flow data were available in portions of the conveyance system where tidal backwater conditions could exist as well as potential backwater conditions from throttling at the WWTPs. The flow measured in these further downstream locations would further be impacted by regulation at in-system control points (regulator, internal reliefs, etc.). During this step in the recalibration, little if any changes were made to runoff coefficients as elements like sediment levels in interceptors had more direct impact on calculated system flows or water depths in sewers.
- WWTP calibration – The final step in the recalibration process was to examine the calculated flows reaching the WWTPs, the most downstream portion of the conveyance system. At this step in the recalibration process, the focus of the recalibration was on both the impervious cover runoff coefficients as well as operational actions taken at the WWTPs to control excessive inflows to the facilities.

1.4 Model Calibration/Validation and Model Accuracy

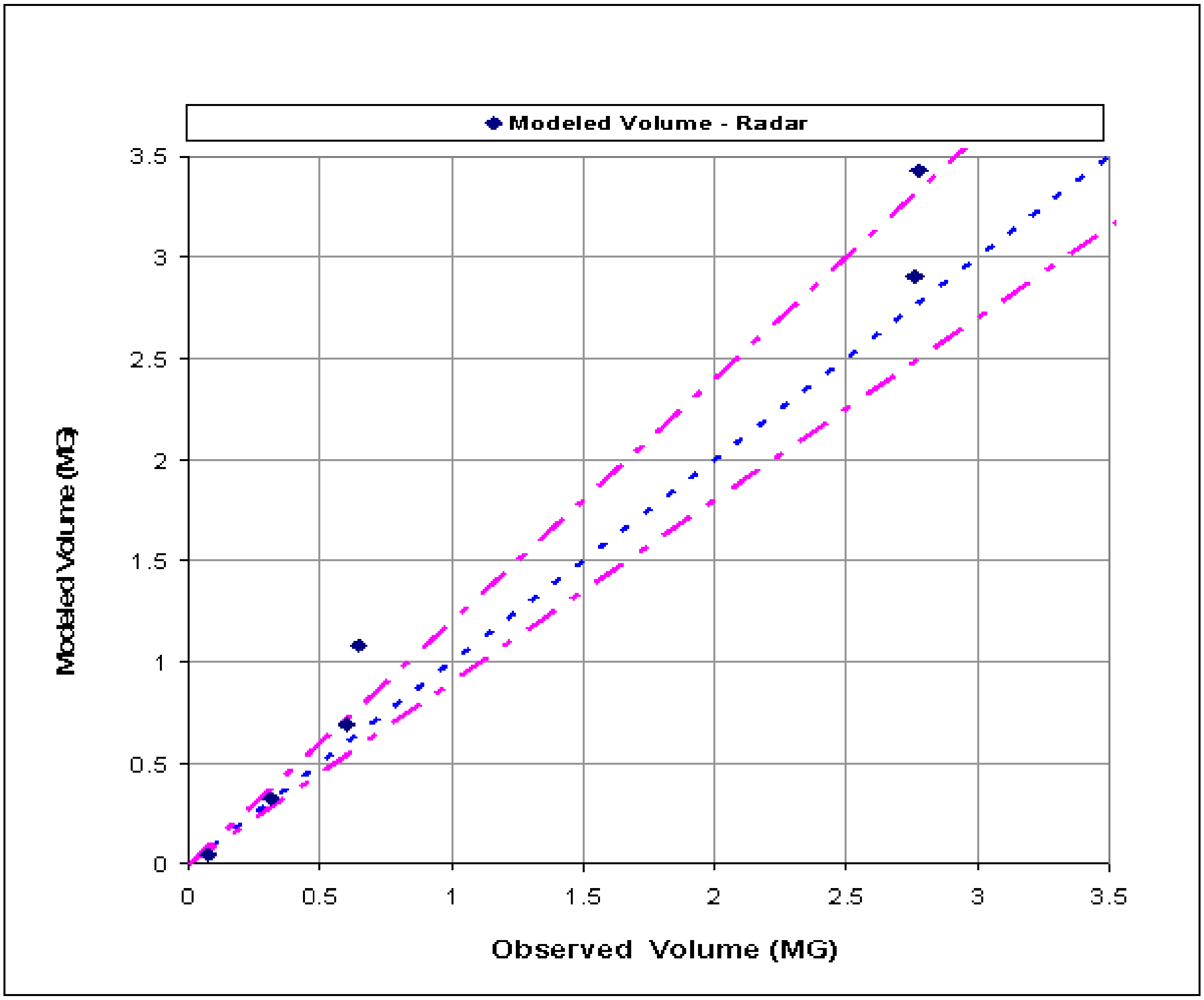
Model calibration involves the use of selected storm events to guide parameter adjustments based on best fit between monitored and modeled flows/depths. Model validation, on the other hand, assesses the model's ability to reproduce observed values for an independent set of storm events not used for calibration.

Collected flow/water depth data were separated into a set that could be used for calibration of the model and another set for model validation. This was only possible during the site-scale recalibration efforts where six to ten storm events were available at each flow metering location. Adequate data were not available for areas further downstream in the system (area-wide recalibration) to allow for individual storm events to be specifically designated for use as model calibration or validation datasets.

Criteria suggested in the Wastewater Planning Users Group (WaPUG, 2002) guidance document were adopted to guide the adequacy of the model calibration. These international criteria are increasingly being used by numerous municipalities in the U.S. The criteria were:

- The timing of the peaks and troughs should be similar, having regard to the duration of the event.
- The difference between observed and modeled peak flow rates at each significant peak should be in the range +25% to -15% and should be generally similar throughout the complete simulation of each event.
- The differences between observed and modeled volume of flow should be in the range +20% to -10%.
- The differences between observed and modeled depth of surcharge should be in the range +16 inches to –4 inches
- The differences between observed and modeled un-surcharged depth at any key points, where this is important to meet the objectives of model application (*e.g.*, at combined sewer overflows), should be within the range ±4 inches.

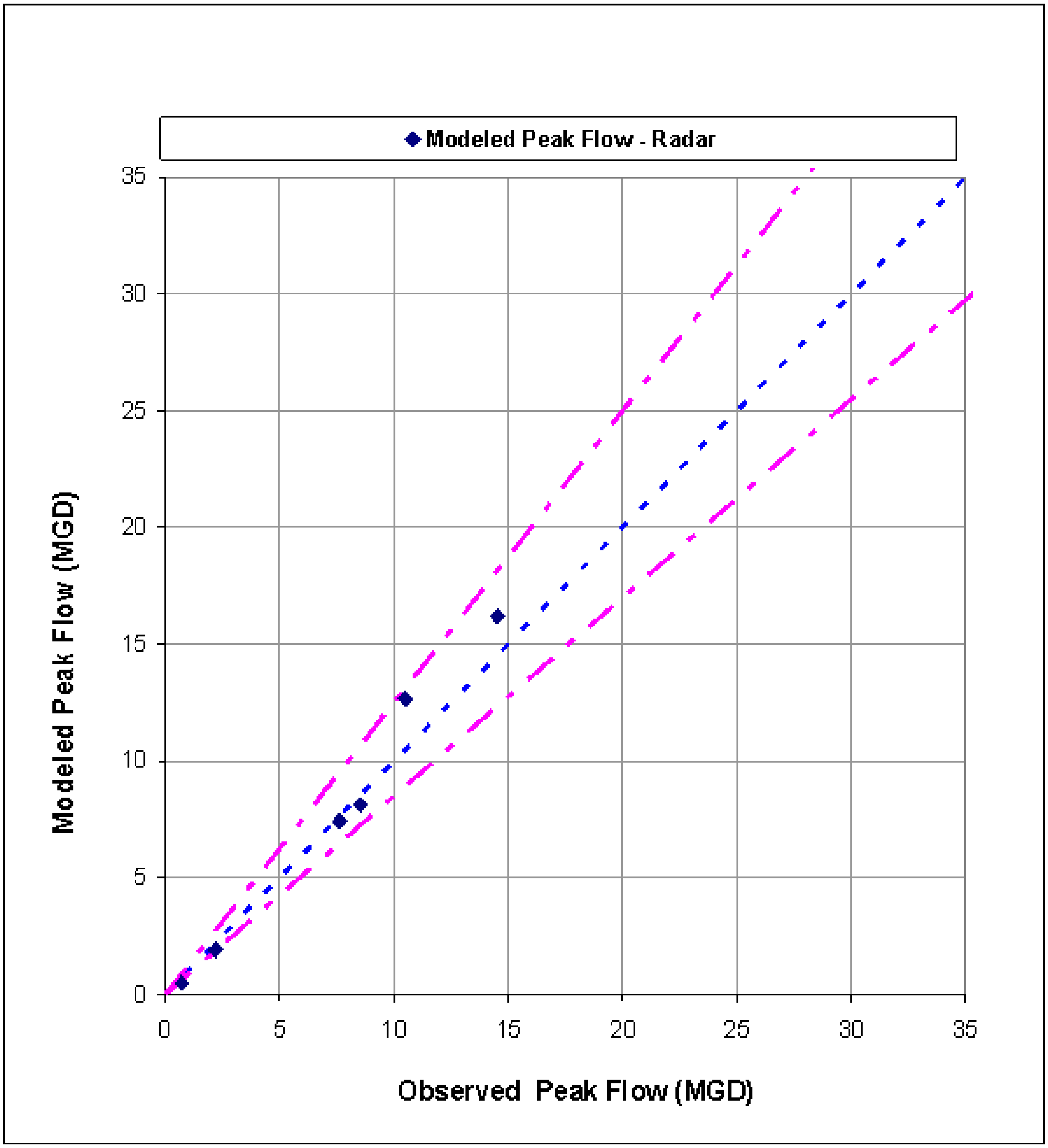
For each calibration and validation event, modeled versus observed hydrographs were generated to evaluate the model performance. In addition, the goodness-of-fit was examined by comparing the modeled event volume, peak flow and maximum water depth for all events to the observed data in goodness-of-fit scatter plots. The upper and lower WaPUG calibration criteria bounds were marked for the comparison in goodness-of-fit plots. Figures 1-2a, 1-2b, 1-2c and 1-3 show examples of the goodness-of-fit scatter plots and temporal plots.



Example Goodness-of-Fit Scatter Plot for Modeled and Observed Flow Volume

NYCDEP Citywide InfoWorks Recalibration Report

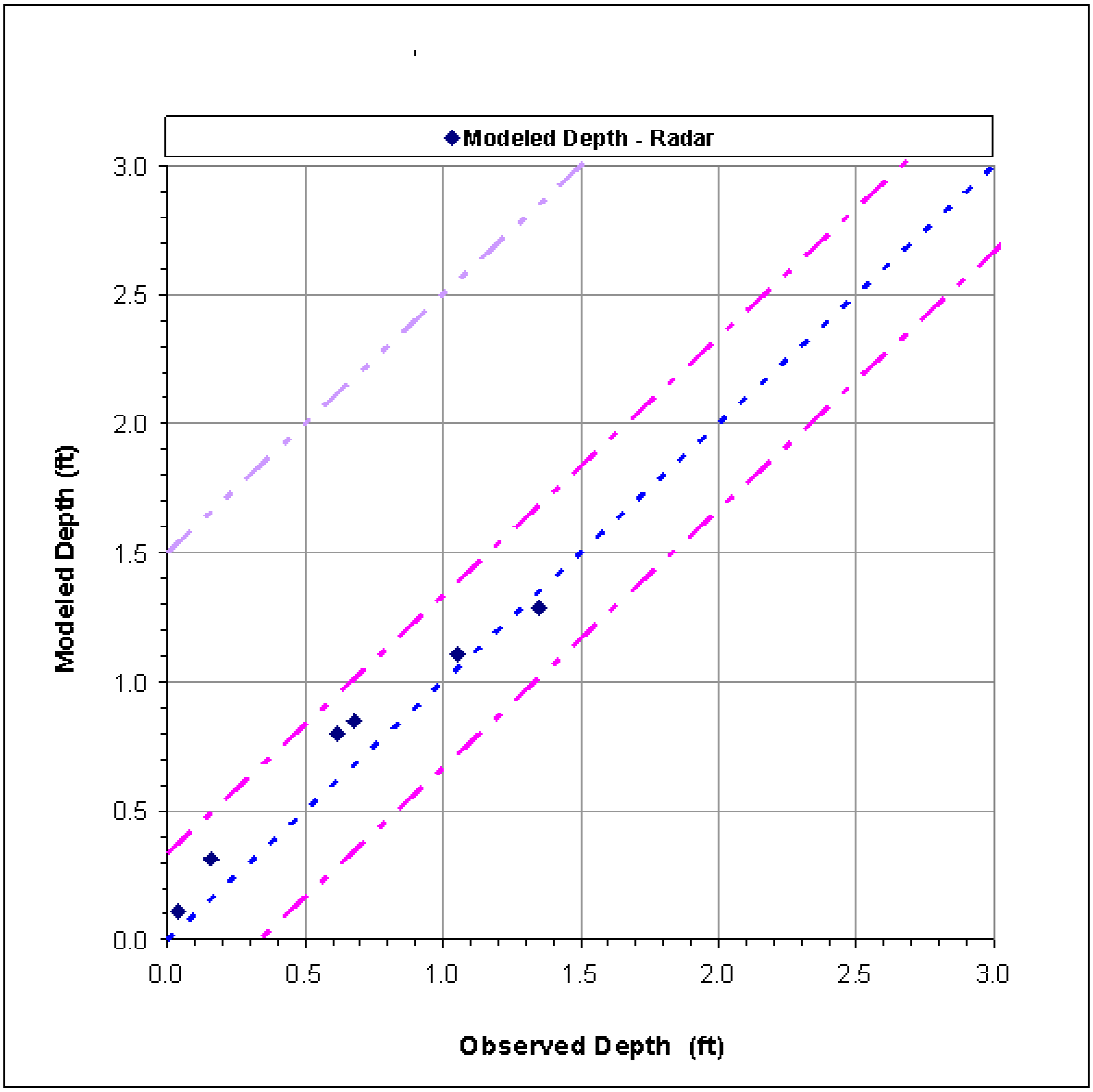
FIGURE 1-2a



Example Goodness-of-Fit Scatter Plot for Modeled and Observed Peak Flows

NYCDEP Citywide InfoWorks Recalibration Report

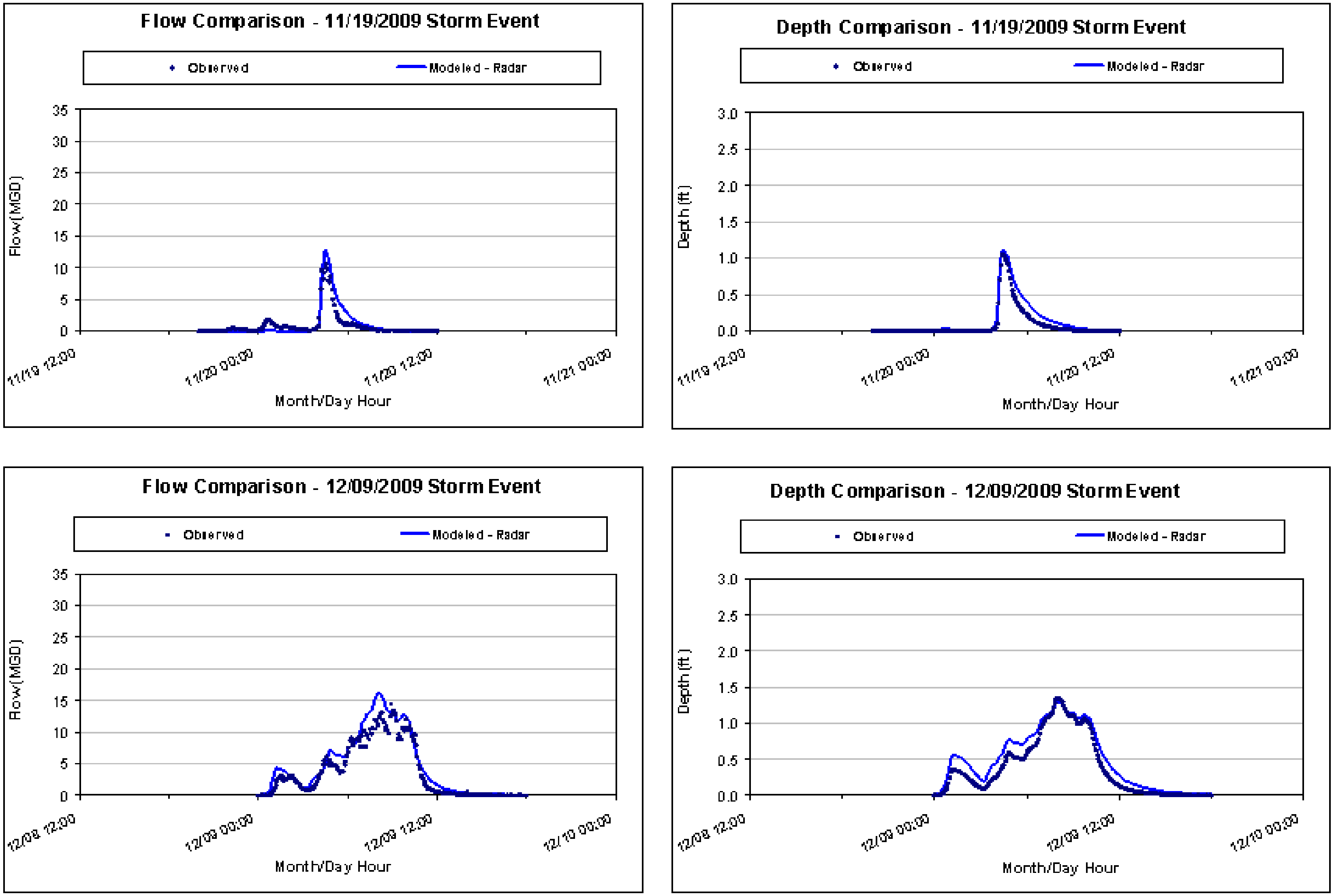
FIGURE 1-2b



Example Goodness-of-Fit Plot for Modeled and Observed Peak Flow Depths

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 1-2c


Flow Comparison - 11/19/2009 Storm Event

Depth Comparison - 11/19/2009 Storm Event

Flow Comparison - 12/09/2009 Storm Event

Depth Comparison - 12/09/2009 Storm Event

Example Temporal Plots for Modeled and Monitored Comparions

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 1-3

Section 2.0
Model Changes Since the Development of the October 2007 Landside Modeling Reports

As noted in Section 1, the InfoWorks CS modeling software, versions 6.5 and 7.0, were used in the work documented in the October 2007 reports. Version 10.5, being a more up-to-date version of the model, was employed in all analyses described in this report. This allowed all of the sewer system models to be maintained in the most updated and advanced version available at this time.

This section provides an overview of changes made to various elements of the models during these recalibration activities. These changes represent modifications of a global nature. More site-specific modifications made are discussed in Appendices A and/or B for each of the WWTP collection system IW models.

2.1 Input Changes that Influence Calibration Parameters

The following portions of this section describe global changes made in the IW models that are structural in nature and are generally applicable to all calibration or future condition simulation periods for which the model would be applied.

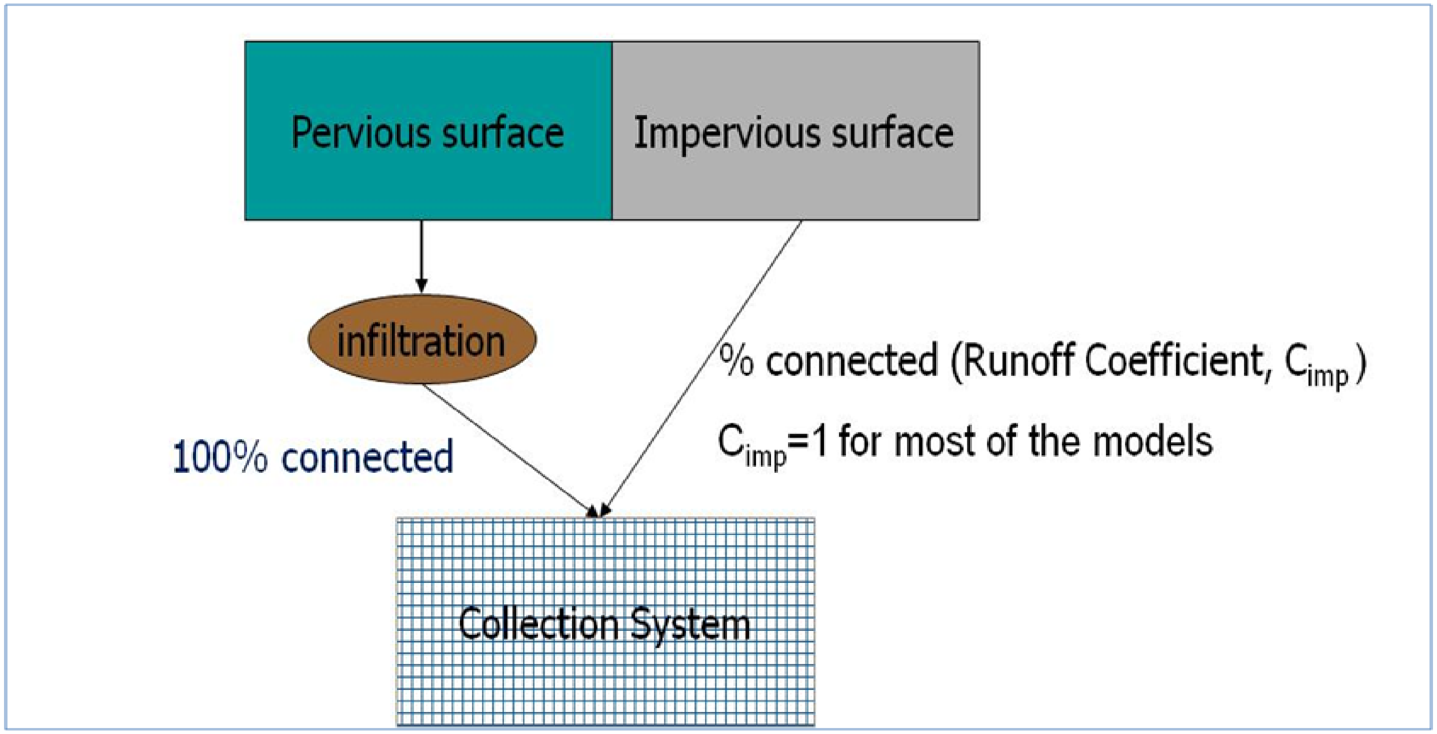
2.1.1 Runoff Generation Methodology

A major change made to the IW models was the way in which the subcatchments were set up to generate runoff from land surfaces. Figure 2-1 provides a schematic of the subcatchment structure in the previous application of the IW model to the NYC sewersheds. Each subcatchment was represented by two different surfaces that had unique characteristics.

Pervious surfaces
Pervious surfaces were considered to infiltrate rainfall into soils based on the Horton equation (defined in glossary). The basic premise of the Horton equation was that the amount of infiltration within the soils was based on the hydrologic soil group classification and that rainfall would continue to infiltrate as long as the intensity was less than the soil absorption capacity. More intense or prolonged rainfalls would produce runoff which would enter the collection system.

Impervious surfaces
Impervious surfaces in the previous version of the model were considered as Directly Connected Impervious Areas (DCIA) that aside from a small amount of initial loss (depression storage) would have a runoff coefficient of one. This basically dictated that all rainfall falling on impervious surfaces would directly result in runoff.

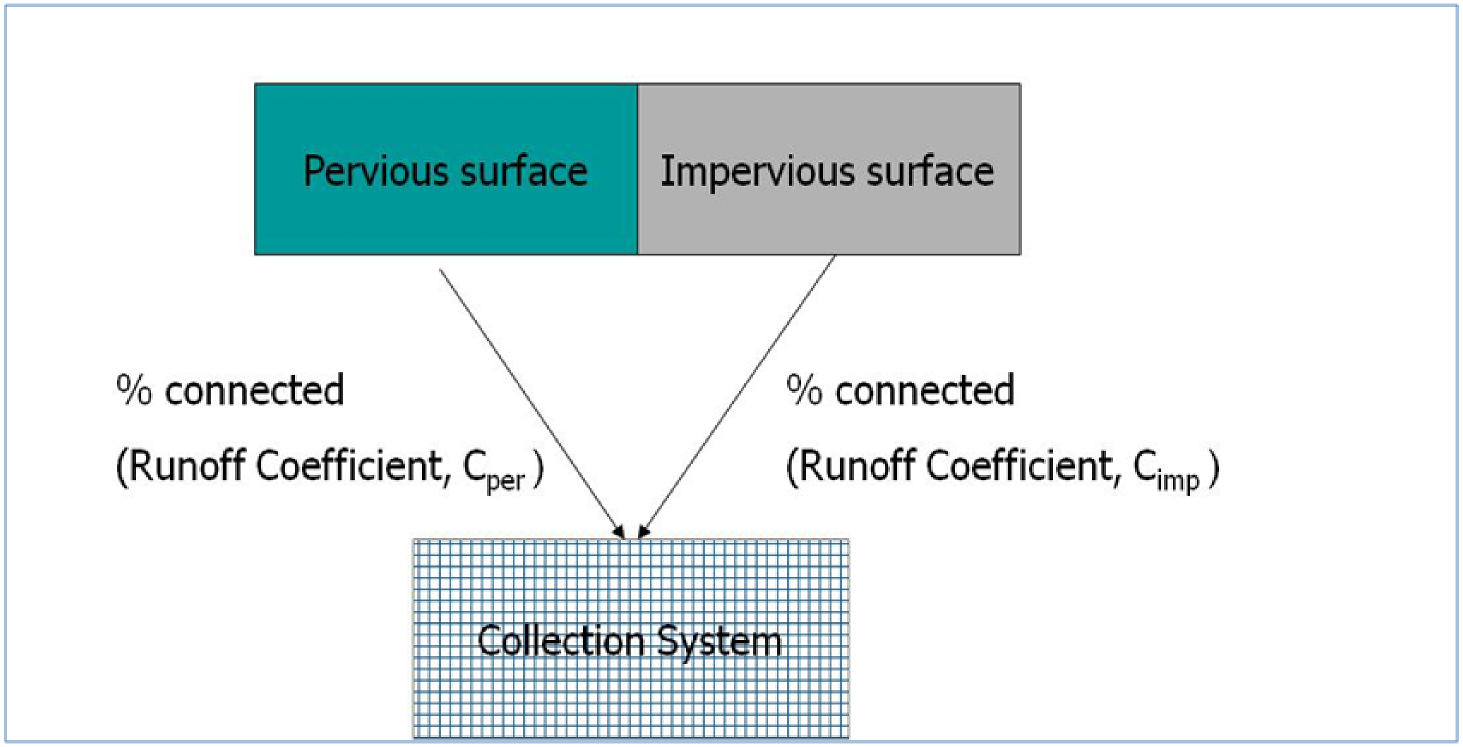
This approach to modeling surface runoff was changed during this recalibration effort. The directly connected impervious area (DCIA) is the fraction of total or gross impervious area for a subcatchment that contributes runoff to the collection system. The DCIA values were used as runoff coefficients for impervious areas, which were adjusted during calibration to allow modeled output to match observed data. Similarly, the runoff coefficients were used for pervious surfaces also (refer to Figure 2-2).



Schematic of October 2007 Version of IW Models

FIGURE 2-1

NYCDEP Citywide InfoWorks Recalibration Report



Schematic of New DCIA Method

FIGURE 2-2

NYCDEP Citywide InfoWorks Recalibration Report

Pervious Surfaces

The runoff coefficient approach was adopted for the model after researching the types of soil and infiltration data available from the NYC Water and Soil Conservation Service, to support the development of a physically based infiltration model for the pervious areas. In short, the available data did not provide additional insight on surface infiltration characteristics to allow refinement or continued use of the Horton equation approach to characterizing runoff behavior from pervious surfaces. As such, two types of pervious surfaces were developed for each subcatchment and appropriate land areas developed from GIS analyses; open space pervious surfaces and non-open space pervious surfaces. Open space pervious surfaces included parks, cemeteries, highway medians and similar surfaces where surface soils were not subjected to compaction by constant use. Non-open space surfaces were defined as pervious areas in developed landuses where soils would likely be compacted through use. Open space pervious surfaces were assigned a runoff coefficient of 0.2 while non-open pervious surfaces were assigned a value of 0.4. These coefficients were consistent with the DEP drainage planning design values as well as those commonly used in other similar modeling assessments.

Impervious Surfaces

The runoff coefficient for impervious surfaces was assigned an initial value of 1.0. However as it was recognized that the DCIA's were the areas of interest since they produce the runoff that would reach the collection system, the imperious area runoff coefficient was treated as the primary calibration parameter during model recalibration. As a result, the starting value for impervious surfaces was the area provided by the Columbia University remote sensing data analysis. The final value for the DCIA in acres would then be the area provided by Columbia University analysis multiplied by the final runoff coefficient for impervious area developed during recalibration. This resulted in an approach that utilized the detailed imperviousness data, while controlling the runoff predicted from those surfaces through a coefficient, such that modeled output matched observed data reasonably well.

In order to simulate runoff from impervious areas that have little or no initial rainfall losses (depression storage), one fourth of the impervious areas were assumed to have no initial losses - an assumption made based on site-scale data analyses. For example, the sloped roofs would only induce initial losses through wetting but there would be no ponding on these surfaces. Other impervious areas such as flat roofs, sidewalks and roads would have surface depressions or potholes that cause additional initial losses. Thus, the total drainage area in a subcatchment was subdivided into four types of surfaces: impervious surface without depression storage, impervious surface with depression storage, pervious non-open surface and pervious open surface.

2.1.2 Columbia University Impervious Coverage

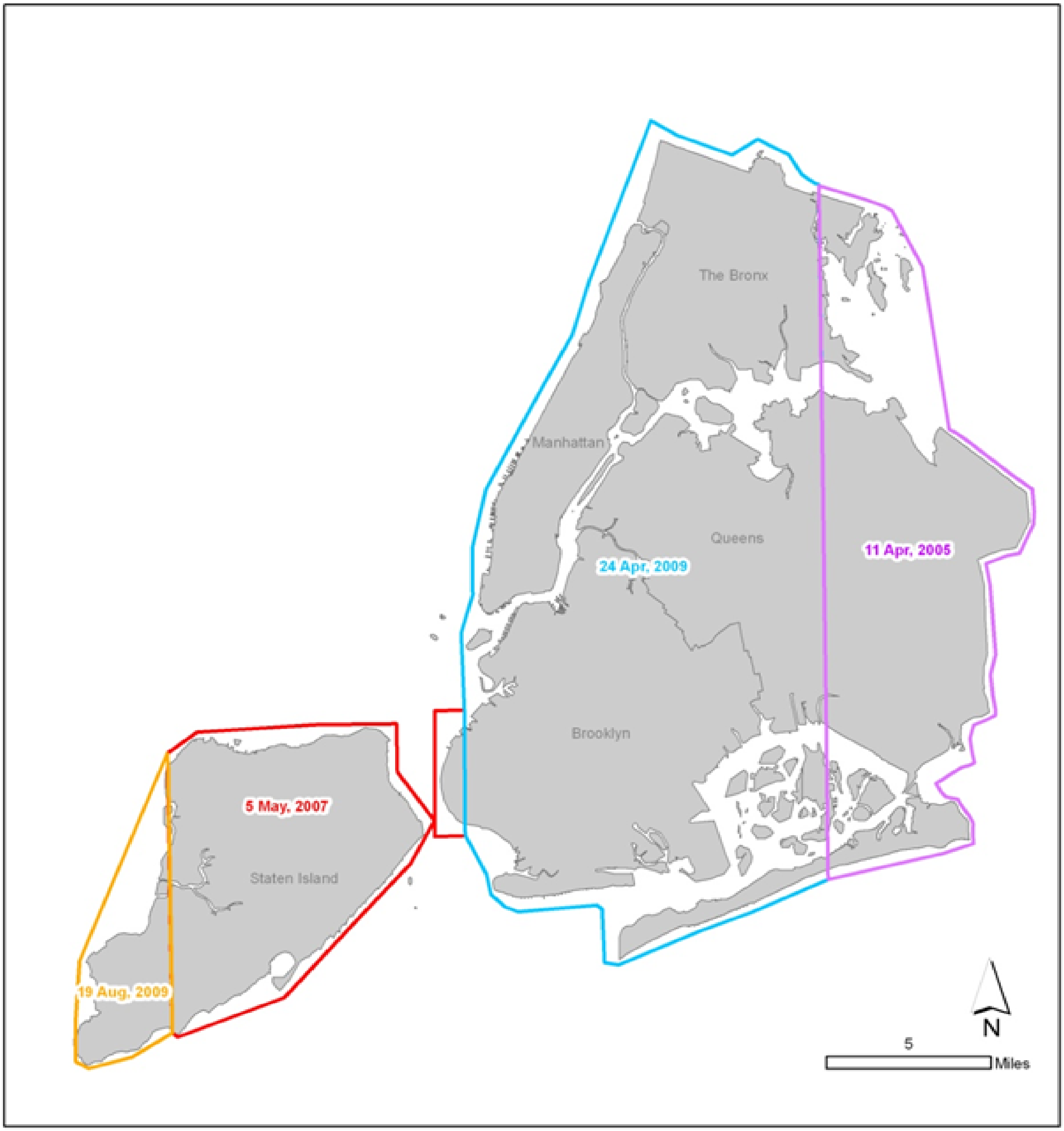
As noted in Section 1, the October 2007 version of the IW model used GIS methods to identify DCIA. To enhance the ability to identify impervious surfaces beyond those street and building GIS layers, DEP retained Columbia University to use satellite remote sensing data and to measure the total impervious areas of New York City. Mapping impervious surfaces in urban areas is difficult because almost all of the available analysis methods are based on the assumption that the land covers or surfaces being classified have unique or at least distinguishable, reflectance properties. For many land cover types, like vegetation, water, ice, snow and some rocks and soils, this assumption is valid but for impervious surfaces it is generally not valid. In short, permeability is a physical property but not an optical property.

The diversity of impervious surface reflectances has considerable overlap and similarity to pervious surface reflectance because many impervious surfaces are composed of the same materials found in pervious surfaces. Sand and carbonates are common examples. For this reason, even hyper-spectral sensors cannot generally distinguish pervious and impervious surfaces on spectral characteristics alone. The problem is even more difficult with broadband sensors used in commercial satellites like LandsatTM and QuickbirdTM. An alternative approach developed by Columbia University was to first map pervious surfaces at high spatial resolution. Many soils have more diagnostic reflectance properties than impervious surfaces. In areas where soils support vegetation, it is possible to exploit its unique spectral reflectance properties to make detailed vegetation maps as proxy for pervious surfaces. In short, mapping pervious surfaces accurately allows for the remaining areas to be calculated as being impervious.

To accomplish this, Spectral Mixture Analysis (SMA) of high spatial resolution Quickbird multispectral imagery was used to map bare soil and vegetation within the watersheds draining into the NYC area. SMA is a physically-based mapping technique in which the reflectance of each pixel is represented as a mixture of a limited number of end-member reflectance (signal strength at various wavelengths) and a linear mixture model is developed to yield optimal estimates of the areal fraction of each end-member within each pixel in the image. These comparative analyses, as well as more detailed studies conducted in NYC (Small, 1999, 2001; Small & Lu, 2006) indicate that vegetation and soils were almost always present as spectral end-members in urban areas and could be mapped with rigorously verifiable accuracies in excess of 94% with Landsat imagery validated with Quickbird (Small & Lu, 2006). A major advantage of SMA over traditional statistical thematic classifications is that the resulting fraction maps can be validated unambiguously and are not vulnerable to the same subjective accuracy bias that thematic classifications are. As such, the SMA was used herein to produce maps of vegetation and soil abundance and a decision tree classification applied to convert the fraction maps to high resolution maps of pervious surface proxy.

The SMA approach described above was applied to high spatial resolution 7.9 ft x 7.9 ft (2.4m) for the NYC watershed area. Quickbird images in three visible bands (red, green, blue) and one near infrared spectral band were obtained through commercial purchases. The images were acquired in a 9.7 mile wide (16 km) swath with mid-morning overpass times that varied according to the satellite's orbital parameters and the viewing angle. Images used early spring leaf-off imagery to assure maximum distinguishability of vegetated area as well as maximum solar zenith angle to minimize shadow extent. Figure 2-3 shows the areas of the City for which the satellite data were purchased to conduct this analysis. An attempt was made to purchase all data from exactly the same timeframe, however, because of cloud cover and rainy conditions only the April 2009 image could be obtained under the ideal leaf-off late spring condition. The remaining images from April 2006, May 2007, and August 2009 were acquired to supplement the 2009 data set and provide a complete coverage of the entire City.

The resulting soil and vegetation fraction maps were validated using higher resolution (< 3ft) color visible imagery acquired during leaf-off conditions from traditional aerial photos. Once the fraction maps were validated the continuous fractions were hardened into thematic soil, vegetation and shadow maps, all pervious surfaces, using a decision tree classification. The result of the Columbia analysis was a GIS layer for pervious surfaces at a 7.9 ft (2.4 meter) pixel basis. Impervious surfaces were taken as the inverse or the remaining non-pervious surfaces. An example of the end-product is shown in Figure 2-4 for an area in the Bronx where site scale flow metering was performed (Section 3). In Figure 2-4, the green areas represent the pervious surfaces while the non-green areas would be the impervious surfaces. Again as noted not all of these impervious surfaces will be DCIA's.



Date of Satellite Data Purchase

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 2-3

Bronx - 50 feet southeast of Edson Avenue along E222nd Street

Example Map of Pervious and Impervious Areas

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 2-4

2.1.3 GIS Aligned Model Networks

The October 2007 IW models were built from efforts undertaken over the past three decades of CSO facility planning. The basis of the models has generally been the maps of the collection system compiled during the Infiltration and Inflow studies (i.e., I&I maps) conducted throughout the early 1980's and the late 1990's. Information extracted from these maps, supplemented with information on the regulator structures from the Regulator Improvement Program Project and as-built drawings and field inspections, provided the information that went into constructing the sewer piping network in all of the IW models.

Over the last decade the Bureau of Water and Sewer Operations (BWSO) of DEP has been developing a sewer system GIS. This dataset, when completed and quality checked, will contain the most up-to-date information available on the existing sewers, regulators, outfalls, and pump stations in all areas of the City. During model recalibration early steps were taken to use information from this dataset where the quality checks had been completed An initial review of the Red Hook WWTP combined sewer system tributary to the Gowanus Canal indicated that there were some small differences in the total drainage area tributary to the canal (models vs. GIS maps), with the total areas being different by a few percent.

DEP will continue to integrate this GIS dataset in all the IW models after completion of this recalibration effort to assure that the models reflect the latest information available on the sewer system. This effort will be a continuous process that will result in some further refinement to the models that will be made during development of the LTCPs. However, based on the initial review of the Gowanus Canal tributary area, it is expected that these changes will be minor and will not result in the need to further adjust the model calibration parameters on a city-wide level.

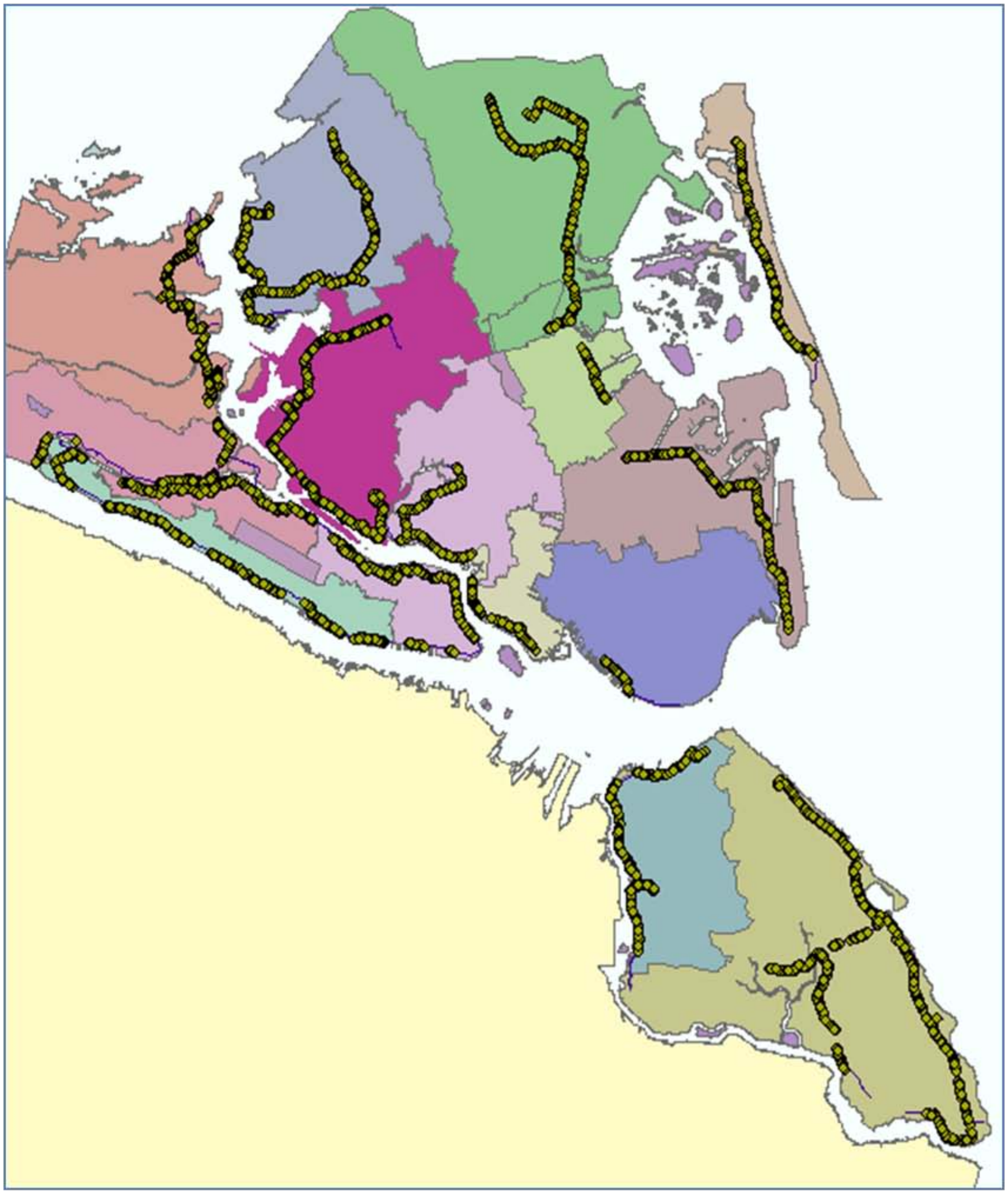
During recalibration, the spatial alignment of the models to streets and other physical features was enhanced. For the most part, the October 2007 versions of the models did not correspond with high accuracy to physical space. The models contained high vertical accuracy, containing proper pipe lengths and slopes, but those pipes did not always align horizontally with their exact respective locations on the streets. It should be noted that horizontal alignment accuracy does not materially affect hydrology or hydraulics calculations, but it impacts the way the modeled system is mapped in figures and represented among other physical features in a GIS environment. This situation was rectified in 2010 when each of the modeling networks and respective subcatchments were properly aligned to provide the models with a more accurate horizontal physical representation.

2.1.4 Interceptor Sediment and Cleaning Data

DEP recently completed a City-wide interceptor sediment inspection and cleaning program. From April 2009 to May 2011, approximately 145 miles of the City's interceptor sewers were inspected. Data on the average and maximum sediment in the inspected interceptor sections were available for use in the models as part of this recalibration process. GIS-based inspection data were used to add sediment to the interceptors for each of the IW models as part of this recalibration exercise. Areas where data were available are shown in Figure 2-5.

FIGURE 2-5

Inspection and Sediment Data Map



NYCDEP Citywide InfoWorks Recalibration Report

In addition, DEP provided average sediment levels in each interceptor segment estimated using data collected from the inspections. These average values were used as the initial interceptor sediment values during model recalibration. As discussed in later sections of this report, during model recalibration some changes were made to these sediment values in order to obtain better match between observed and modeled flows and water depths. Assigned sediment values were assumed to be present in the interceptors for all calibration periods prior to 2011.

DEP also developed GIS files containing information on interceptors that were cleaned between July 2010 and December 2011. A total of 4,606 yd^3 (7,125 tons) of material in 65,839 linear feet of interceptors was cleaned throughout the City during this period. Forty-seven (47%) percent of the total sediment was from the Tallman Island WWTP drainage area, which was removed between March and November 2011; and 24% of the sediment was from the Jamaica WWTP drainage area, which was removed between August 2010 and March 2011. The models were updated for 2011 simulation periods, with the average sediment depths applied uniformly to the corresponding model conduits. Interceptor sediment cleaning data from 2012 will be incorporated in future versions of the models.

2.1.5 Evapotranspiration Data

Evapotranspiration (ET) is another meteorological input (in addition to rainfall) to the hydrology module of the IW model. Monthly varying ET rates are deducted during rainy periods in the calculation of precipitation excess, that equals the runoff generated from both impervious and pervious surfaces. In addition, for continuous model simulations, the volume of depression storage (surface ponding) is depleted based on the evaporation specified in the model. These depression storage areas once emptied by evaporation are available for use for additional surface ponding during subsequent rain events. In the 2007 LTCP models, an average of 0.1 inches/hour (in/hr) evaporation rate was used for model calibration, while no evaporation rate was used as a conservative measure during alternatives analyses.

The Northeast Regional Climate Center (NRCC) affiliated with Cornell University has developed a semi-physical model which estimates hourly ET. Continuous hourly ET estimates were obtained from Cornell for the four New York City NOAA climate stations (John F. Kennedy International Airport, JFK; Newark International Airport, EWR; Central Park, CPK; and LaGuardia Airport, LGA) for an 11-year period from 2000 to 2011. The data were then used to calculate monthly average ET. The monthly average ET rates developed from these long-term data are plotted in Figure 2-6. The monthly rates are given in Table 2-1 and the long term average annual total ET volume for each station is summarized in Table 2-2.

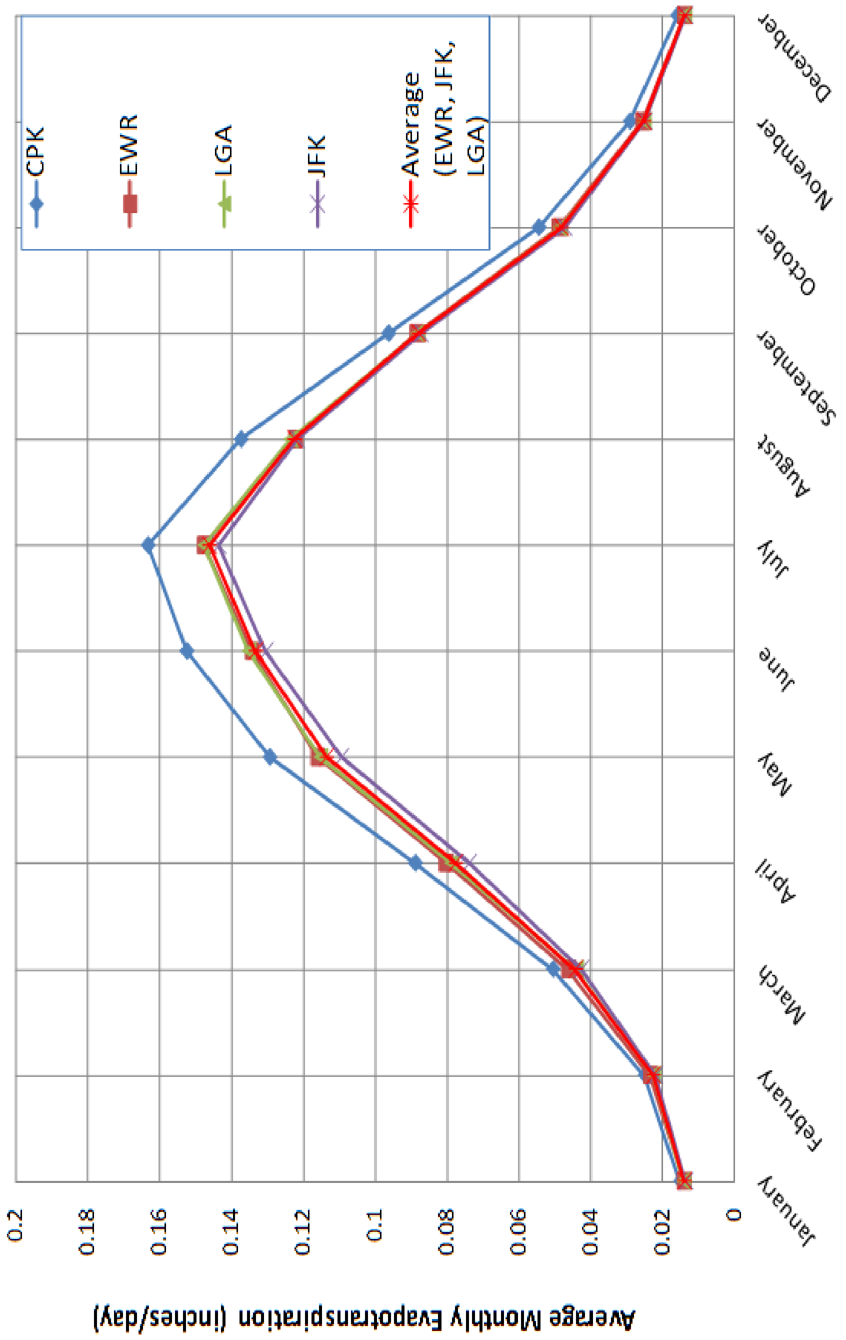
Table 2-1 Monthly Average ET Rates (2000 to 2011) (inches/day)

Month	CPK	EWR	LGA	JFK	Average Based on EWR, LGA and JFK
January	0.015	0.014	0.014	0.014	0.014
February	0.025	0.024	0.023	0.022	0.023
March	0.051	0.046	0.044	0.043	0.044
April	0.089	0.080	0.079	0.074	0.078
May	0.130	0.116	0.115	0.110	0.114
June	0.153	0.134	0.135	0.131	0.133
July	0.163	0.148	0.148	0.144	0.146
August	0.138	0.122	0.124	0.122	0.123
Septembe	0.096	0.089	0.088	0.087	0.088
October	0.055	0.049	0.049	0.047	0.048
November	0.029	0.026	0.025	0.025	0.025
December	0.016	0.014	0.014	0.014	0.014

Table 2-2 Annual Total for 2011 and Long-term Potential Evapotranspiration Average (2000 to 2011)

Station	2011	Long-term (2000 to 2011)		
		Maximum	Average	Minumum
CPK	29.51	31.55	29.30	26.79
EWR	26.68	27.97	26.34	23.84
LGA	26.30	27.96	26.22	23.77
JFK	25.62	27.34	25.41	22.87

As seen in Tables 2-1 and 2-2 and Figure 2-6, ET estimates at EWR, JFK and LGA are similar both in terms of monthly averages and annual totals. Variation between the three stations is within 2 percent of the average annual total ET. CPK ET appears to be very different and about 12 percent higher than the average ET of other three locations. Although the data provider could not confirm the reasons for this difference, it is suspected that vegetation cover around CPK station may have played a role, as is evidenced by the fact that the CPK ET is significantly higher than the ET of the other three locations during summer periods with the largest deviations in June and July. As EWR, JFK and LGA provide consistent estimates, which are likely more applicable to the urban areas of the City, the average ET rates for these three stations developed from 2000-2011 data was used in the models. This average is shown as the red line in Figure 2-6 and given in the last column in Table 2-1.



Monthly Average ET Estimates (2000 to 2011)

FIGURE 2-6

NYCDEP Citywide InfoWorks Recalibration Report

2.1.6 Tidal Boundary Conditions at CSO Outfalls

Tidal stage can affect CSO discharges when tidal backwater in a CSO outfall reduces the ability of that outfall to relieve the excessive flow. Particularly when the outfall is equipped with a tide gate flap valve, the backwater condition caused by high tides can reduce or eliminate periods of CSO discharge from that outfall. Depending on the duration of rainfall and the wet weather flow conditions in sewers, additional flow from the interceptor or combined sewers may be conveyed to WWTPs due to this backwater conditions. Representation of tidal effects, therefore, allows us to accurately characterize these dynamic hydraulic conditions in the model.

NOAA measures hourly tidal stage at three long-term “reference” stations in New York Harbor: The Battery, Kings Point, and Sandy Hook (NJ). For analyses of past tidal conditions, a combination of astronomical predictions at satellite stations and meteorological adjustments based on measurements at the reference stations can produce more accurate tidal predictions than astronomical predictions alone. HDR|HydroQual developed a computer program to assist in the computation of the meteorologically adjusted astronomical tides at each CSO outfall in the New York Harbor complex. This model calculates the astronomical tides and adjusts for the longer-term regional meteorological influence. The program then converts calculated tides to the same datum used in the WWTP models. In addition, for outfalls with tide gates, 0.5 feet is added to the tidal boundary condition to account for head losses at tide gates. Most wooden or cast iron tide gates require about 4 to 12 inches of head losses (differential head between upstream and downstream of a tide gate) to open up, so a representative value of 6 inches was used here. This program was used to generate tides for the various calibration/validation periods used here.

2.1.7 Other model updates

Additional changes were made to the 2007 LTCP models as documented in Appendix B for individual models where new system information became available. This includes, among other changes, expansion of the model network in the Gowanus Canal drainage area in the Red Hook WWTP service area, and correction of the contributing subcatchments of OH-006 and OH-007 in the Owls Head area. Details of the updates for individual areas can be seen in Appendix B.

2.2 Input Changes Associated with Recalibration Periods

The following portions of this section describe global changes made in the IW models that are structural in nature and are generally applicable to specific calibration periods.

2.2.1 Dry Weather Sanitary Sewage Flow

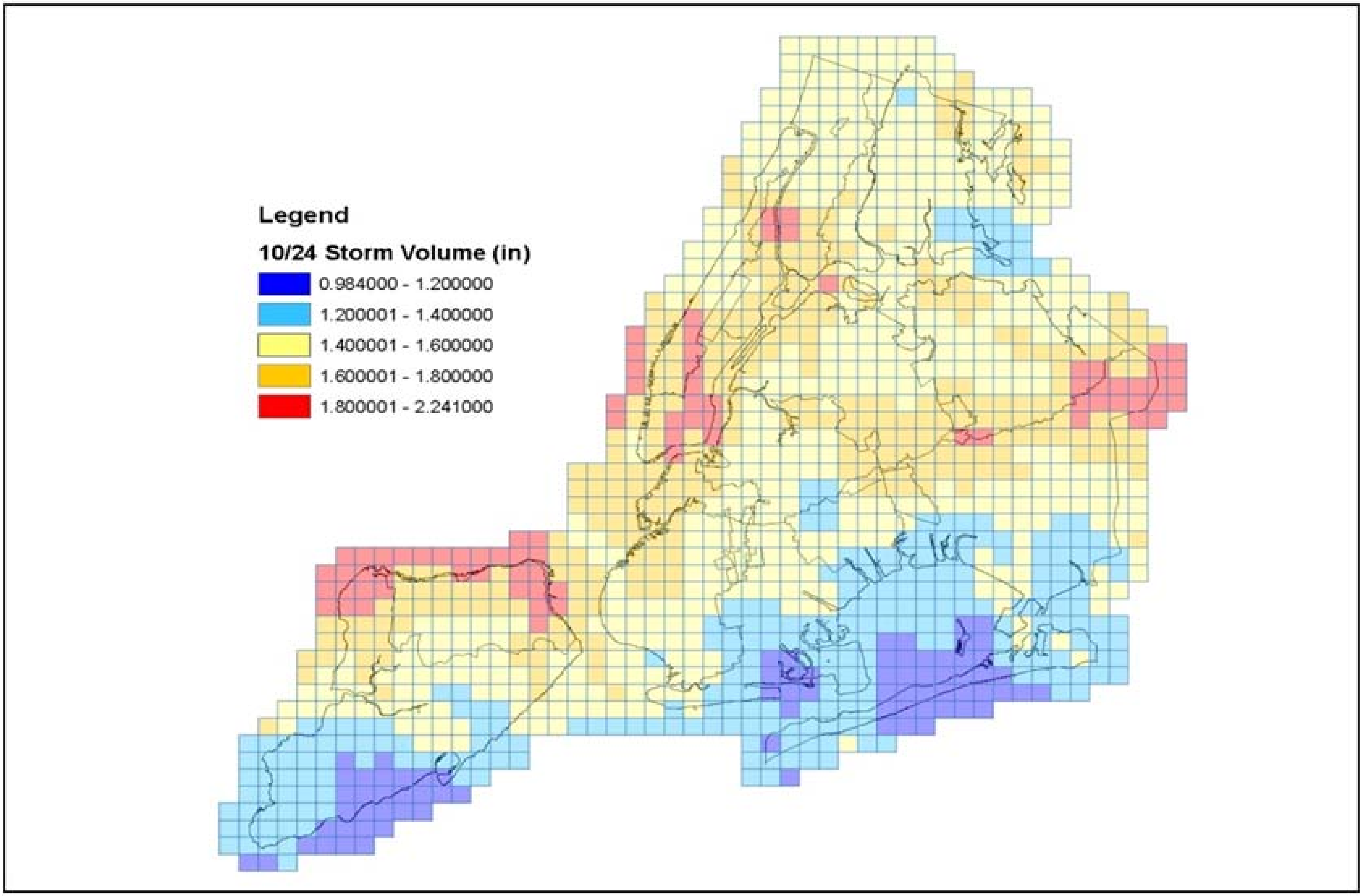
Census population data from 2000 and population allocation among modeled subcatchments were used for event-based area-wide calibrations and described in the October 2007 LTCP model reports. For the 2011 simulations, the models were updated using 2010 Census data and reallocated to subcatchments using the same methodology. Hourly DWF data for 2011 were provided by DEP and used to develop annual average DWF and hourly diurnal variation patterns at each plant. Wastewater generation rates were then calculated by dividing the observed DWF plant flows by the total population in the service area. This wastewater generation rate was then applied to each catchment in the model (and thus to each catchment's population) to arrive at the DWF rates at the treatment plant for 2011. Total population, 2011 average DWF and diurnal patterns for the 13 WWTPs are presented in Table 2-3.

Table 2-3 Summary of Population, Average DWF and Diurnal Used for 2011 Model Simulation

WWTP	2011 Model Input													
	2010 Population	Average DWF (MGD)	Diurnal Variation (Adjustment Ratio Applied To Average DWF)											
			0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00
			12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
26	293,761	50.5	1.01	0.96	0.90	0.85	0.83	0.81	0.82	0.87	0.98	1.08	1.07	1.08
			1.08	1.09	1.09	1.04	1.03	1.03	1.04	1.05	1.06	1.06	1.06	1.04
BB	834,089	105.1	119	115	111	102	92.2	84.7	75.8	71.3	71.3	79.7	92.8	104
			113	119	120	121	119	118	115	114	113	116	118	119
CI	725,374	82.3	1.03	0.99	0.95	0.94	0.88	0.82	0.79	0.82	0.93	1.02	1.07	1.08
			1.08	1.07	1.06	1.03	1.02	1.02	1.03	1.05	1.08	1.10	1.07	1.06
HP	712,718	125.3	1.05	0.98	0.90	0.84	0.77	0.71	0.69	0.78	0.90	1.00	1.06	1.09
			1.11	1.12	1.12	1.11	1.10	1.08	1.08	1.09	1.10	1.11	1.11	1.09
JA	723,179	76.6	1.09	1.01	0.94	0.83	0.76	0.71	0.69	0.74	0.85	1.00	1.07	1.11
			1.13	1.12	1.12	1.11	1.09	1.08	1.07	1.08	1.09	1.11	1.12	1.12
NC	1,140,731	229.1	240	224	191	162	148	143	147	164	199	251	267	268
			272	270	268	261	256	250	251	252	254	255	255	249
NR	606,881	116.8	1.00	0.94	0.85	0.75	0.68	0.63	0.64	0.70	0.87	1.06	1.17	1.20
			1.21	1.20	1.19	1.15	1.12	1.09	1.09	1.10	1.10	1.11	1.08	1.07
OH	772,617	87.7	1.07	0.96	0.83	0.71	0.61	0.55	0.57	0.69	0.90	1.07	1.15	1.17
			1.18	1.16	1.14	1.12	1.10	1.09	1.11	1.14	1.18	1.20	1.18	1.15
PR	216,324	26.7	0.96	0.92	0.87	0.81	0.76	0.76	0.77	0.88	0.94	0.98	1.07	1.14
			1.15	1.16	1.12	1.10	1.08	1.08	1.07	1.09	1.10	1.10	1.09	1.01
RH	202,632	26.7	1.00	0.92	0.83	0.74	0.69	0.67	0.66	0.72	0.90	1.11	1.19	1.23
			1.21	1.17	1.13	1.14	1.09	1.09	1.08	1.06	1.11	1.11	1.08	1.06
RK	140,083	17.1	1.05	1.00	0.94	0.88	0.83	0.80	0.78	0.84	0.90	0.98	1.03	1.06
			1.07	1.08	1.09	1.06	1.06	1.05	1.06	1.07	1.08	1.09	1.11	1.10
TI	432,542	48.7	0.92	0.87	0.8	0.79	0.8	0.84	0.93	1.02	1.08	1.09	1.08	1.08
			1.07	1.04	1.02	1.02	1.05	1.08	1.1	1.13	1.12	1.09	1.03	0.96
WI	1,120,925	196.1	1.08	0.99	0.88	0.79	0.71	0.68	0.67	0.76	0.93	1.07	1.10	1.10
			1.11	1.11	1.12	1.11	1.09	1.08	1.07	1.09	1.11	1.13	1.13	1.11

2.2.2 Precipitation

Site Scale Calibrations - Radar rainfall data for 0.62 miles by 0.62 miles (1km by 1km) grid size (shown in Figure 2-7) that covers the entire City drainage area were obtained for periods that flow meters were installed in 2009 and 2010 in the upstream areas of the collection system to characterize surface runoff. This data was used in the model calibration simulations to accurately represent the spatial variations in rainfall and improve the accuracy of predictions. An exception to this is a site in the 26th Ward area, where 5-min rainfall measurements were taken at a point gage located at the 26th Ward WWTP concurrently with the flow monitoring. This point gage data was used for the 26th Ward model calibration simulations. Additional discussion of the specifics of the rainfall used for site scale calibration are provided in Section 3.



Radar Grid Covering City Drainage Areas and Site-scale Monitored Sites

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 2-7

Area-wide Calibrations

Rainfall data used in the area-wide recalibration efforts varied depending on the time period for which flow monitoring data was available. For the most part, point gauge rainfall data were taken from the hourly NOAA rain gauges at EWR, JFK, CPK and LGA. Table 2-4 shows the rain gauge that was associated with each of the IW model WWTP areas. In a few cases, sensitivity analyses were performed during the recalibrations as described in Appendix B, when it was suspected that the rainfall from one particular rain gauge may not be representative of the total rainfall within an individual sewershed.

WWTP calibration

Year 2011, which was used for the continuous simulation in the WWTP recalibration analysis, was a relatively wet year with several extreme events that occurred in August and September, including Hurricane Irene and Tropical Storm Lee. The total 2011 annual precipitation observed at the four NOAA rain stations (EWR, JFK, CPK and LGA) are in the range of 59.98 to 77.08 inches in comparison to a long-term average of 44 inches. Although this was an outlier year with respect to the amount of total precipitation and the intensity of some of the events, it does prove to be a reasonable test of the model's ability to convey this flow to the WWTPs.

Hourly precipitation records for the year 2011 at the four NOAA rain gages were downloaded and data at the nearest station was used for each WWTP drainage area model, as listed in Table 2-4. During the model recalibration process, when rainfall was believed to be the reason why modeled hydrographs appear to have different responses than the observed data for some events, sensitivity runs using data from an alternative NOAA station were conducted for those drainage areas. The results from these sensitivity runs are discussed in Appendix B.

Table 2-4 Summary of 2011 Precipitation Depth and NOAA Stations Used in WWTP Drainage Areas

NOAA Station	Models Where the Station Used
CPK	NR, RH, NC, WI
EWR	PR
JFK	JA, 26W, RK, CI, OH
LGA	BB, TI, HP

In addition, precipitation in three of the events in January (Jan 11, Jan 20, and Jan 25-26) were in the form of snow, or a mix of snow and rain, and therefore did not appear to produce typical wet weather responses at all of the 13 WWTPs. It was determined that in such cases, runoff from the surfaces would not follow a normal rainfall-runoff translation process; rather, significantly lower peaks and/or longer durations of runoff would be more likely as the snow melts and finds its way to the sewer system. For this reason, these events were eliminated from the calibration comparisons.

2.2.3 WWTP Operations

Particular attention was paid to the operational conditions that existed at the individual WWTPs, for which adjustments in the treatment capacity thresholds had been necessary (*e.g.*, throttling conditions, process units out of service, maintenance work that limited pumping capacity, etc.). These operations would vary among various WWTPs when upgrade/repair work was ongoing, so the hourly plant inflow records were used to represent the varying operating conditions at the treatment plants appropriately.

DEP provided information on WWTP maximum flow rates for periods when throttling controls had been initiated and terminated for the top 10 to 15 storm events in 2011. Table 2-5 summarizes the wet weather capacities (WWCs), and maximum capacities used in the models in comparison to permitted two times design dry weather flows (2XDDWFs) at the 13 WWTP plants. Throttling notes are also included in this table. Due to plant upgrades, construction or maintenance work which occurred in 2011, the 26th Ward, Bowery Bay, Newtown Creek, Port Richmond, Red Hook, Rockaway, and Wards Island WWTPs had a WWC lower than twice the design dry weather flow (2XDDWF), averaging about 1.5XDDWF as shown in the table.

Table 2-5 Wet Weather Capacity, 2XDDWF and Modeled Plant Capacity for 2011

WWTP	Plant Capacity Used In Model (MGD)	2XDDWF (MGD)	2011 WWC (MGD)	Ratio of WWC to DDWF	Ratio of Capacity in Model to WWC	Rain Gage	Notes on 2011 Plant Operation and WWCs
26W	135	170	127.5	1.50	1.06	JFK	Plant maintenance or upgrade in 2011. 127.5 MGD is the WWC listed in DEP top 10 storm analysis table. Recorded flow for some events reached to around 135MGD when plant is throttling.
BB	265	300	220	1.47	1.20	LGA	220 MGD is the WWC listed in DEP' top 10 storm analysis table for most events (some 200MGD and some 240MGD). Recorded flow for some events reached to around 250MGD when plant is throttling.
CI	230	220	220	2.00	1.05	JFK	WWC listed in DEP' top 10 storm analysis table are lower than 2 times for some events, but recoreded flow reached 2XDDWF for extended period when plant is throttling.
HP	415	400	400	2.00	1.04	LGA	

Table 2-5 Wet Weather Capacity, 2XDDWF and Modeled Plant Capacity for 2011 (cont.)

WWTP	Plant Capacity Used In Model (MGD)	2XDD WF (MGD)	2011 WWC (MGD)	Ratio of WWC to DDWF	Ratio of Capacity in Model to WWC	Rain Gage	Notes on 2011 Plant Operation and WWCs
JA	217	200	200	2.00	1.09	JFK	163 MGD is the WWC listed in DEP' top 10 storm analysis table.
NC	730	700	540	1.54	1.35	CPK	2XDDWF in BMP report appendix 1 is marked at 620 MGD. WC listed in DEP' top 10 storm analysis table are mostly at 540MGD. But recorded flow reached 700MGD for extended period when plant is throttling.
NR	360	340	340	2.00	1.06	CPK	Normal operations
OH	256	240	240	2.00	1.07	JFK	240 MGD is the WWC listed in DEP' top 10 storm analysis table for some events (in Mar, Aug, Sep to Dec); for some other events, 180 MGD is the WWC (in Jan to June, Sept, Oct and Dec).
PR	120	120	90	1.50	1.33	EWR	90 MGD is the WWC listed in DEP' top 10 storm analysis table for most of the events when 1 primary tank out of service. recorded flow reached around 100MGD to 120MGD in many events when plant is throttling.
RH	128	120	90	1.50	1.42	CPK	For some events, 90 MGD is the WWC listed in DEP' top 10 storm analysis table, but recorded flow reached 120MGD for extended period when plant is throttling.
RO	90	90	67.5	1.50	1.33	JFK	67.5 MGD is the WWC listed in DEP' top 10 storm analysis table for most of the events, WWC is 51MGD for 3 events in Nov and Dec.
TI	166	160	160	2.00	1.04	LGA	Normal operations
WI	515	550	420	1.53	1.23	CPK	420 MGD is the WWC listed in DEP' top 10 storm analysis table for most of the events. Recorded flow varies, mostly around 450 - 500 MGD range.

2.3 Source of Model Calibration Data

The primary sources of information used for calibration and validation of the IW models were flow and water depths measured within combined sewers and interceptors. These data sources are described in detail in Sections 3 and 4 of this report as well as in Appendix A and B. Additional sources of data used in the calibration analyses included the following.

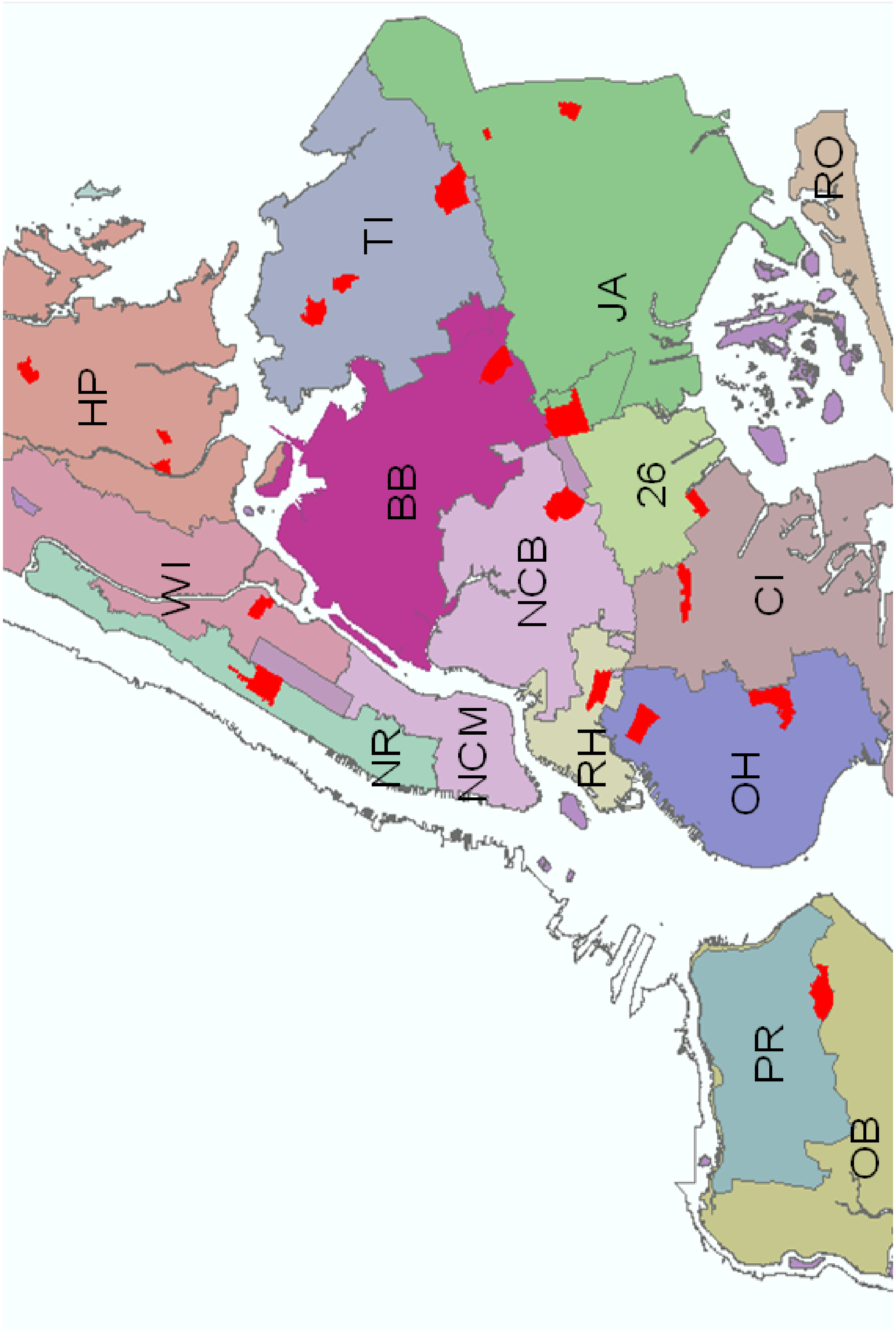
- WWTP Influent Flow – Hourly treatment plant influent flow was used for use in the areawide model calibrations described in Section 4 of this report. This data was available for all years within which calibration analyses were conducted. However, of particular interest for this recalibration analysis was the year 2011 WWTP influent flow data, which is used herein for the areawide WWTP calibration analyses described in Section 4 and in Appendix B.
- CSO Retention Facility Flows – Limited flow data from Flushing Creek CSO retention facility exists and was used herein in the areawide calibration analyses as described in Section 4 and Appendix B. In addition, monthly Post Construction Monitoring (PCM) overflow volumes reported for the year 2011 were available and were used in the calibration analyses for the Flushing Creek, Alley Creek and Paerdegat CSO retention facilities. Overflow volumes from the Spring Creek PCM monitoring were not used here as the data do not appear to accurately represent reasobably overflow volumes.
- SCADA data – Data were not available from the SCADA system for use in the recalibration analyses. Data at a number of regulators from the predicesor systems to the SCADA sysem were examined but were not included in the calibration analysis as they provide only water elevatipons and they do not provide flow data, which was the main parameter of concern for this recalibration analysis.

Section 3.0
Site-scale Calibration

3.1. Site-Scale Monitoring and Site Characteristics

Calibration of the hydrology module of IW models using Columbia University Impervious Data and the DCIA method was first conducted on a site-scale level using metered data collected at 20 sites located in different drainage areas of the City. This site-scale calibration was necessary before the model parameters that influence runoff could be applied to the models on a larger area-wide basis

Figure 3-1 presents the location of the 20 metered sites distributed in various WWTP drainage areas: three in HP, two in NC, three in JA, two in OH, three in TI, and one each in 26W, BB, CI, NR, PR, RH, and WI. The metered sites were all located in upstream areas of the collection systems, where system hydraulics had little to no impact on the runoff response to rainfall events (no backwater from tides or plant throttling, regulator restrictions, etc.). Some of which were beyond the 2007 model extent. The models were expanded, as necessary, to include the metered sewers. This generally required subdividing catchments into a number of smaller subcatchments and adding additional lengths of pipes to the sewer network. Delineation of drainage areas were refined based on I&I sewer maps, street layouts and aerial photographs to best represent the contributing areas. Subcatchment boundaries were overlaid on the Columbia University Impervious Data to calculate percent imperviousness in each model subcatchment. The sizes of drainage areas ranged from 15 to 400 acres, small enough that they would be representative of varying land uses and amounts of impervious cover, but large enough that localized effects (*e.g.*, basement flow pumping from homes) would not be significant. Also, the distribution was chosen to make sure that the model parameterization developed at this local level can be scaled up to other unmonitored areas during WWTP drainage area-wide application. The meters were installed in relatively straight pipe runs and were located at a sufficient distance from interconnections and bends, so the measured flows were not subject to local turbulence. The sizes of sewer pipes where the meters were installed were larger than 30 inches to ensure reliable measurements by the depth and velocity sensors. Percentages of each type of surface, based on integration of Columbia University Impervious Data and land use data, for the 20 site scale subcatchments are listed above in Table 3-1. The selected sites are representative of the entire range of the percent of imperviousness in New York City, ranging from 30 percent or less to 90 percent or above. An example map of a subcatchment and drainage area tributary to a site scale flow monitoring site for the North River site (Metering Site #22) is shown in Figure 3-2. This figure also shows the various surface categories for the North River site. Appendix A provides drainage area maps and surface area maps of all 20 sites.



Location of the 20 Site-scale Metered Drainage Areas

FIGURE 3-1

NYCDEP Citywide InfoWorks Recalibration Report

Table 3-1 Summary of Characteristics of 20 Site-scale Sites and Their Drainage Areas

Site ID	WWTP	Total Area (Acres)	Drainage Area Sufaces			Metered Pipe Size	Street Intersection	Monitoring Period
			% Impervious	% Pervious-Non Open	% Pervious - Open			
HP #10	HP	26	95	5	0	34" X 45"	150ft E of Fteley along Gleason Ave	Oct - Dec 2009
HP #12	HP	42	99	1	0	60"	50ft S of Westchester Ave along Colgate Ave	Oct - Dec 2009
TI #1	TI	131	75	21	4	42"	100ft N of 26th Ave along 146th St	Oct - Dec 2009
TI #2	TI	326	30	13	56	60"	150 ft S of 73rd Ave along 196th Pl	Oct - Dec 2009
TI #3	TI	71	53	39	8	33"	100 ft E of 161st St along 35th Ave	Oct - Dec 2009
BB #13	BB	193	66	32	2	48"	Intesection of Austin St & 70th Ave	Oct - Dec 2009
NC #6	NC	189	25	2	74	42"	100ft NW of Cooper Ave along Cypress Street	Oct - Dec 2009
NC #7	NC	69	72	9	19	78"	Cypress Ave between Norman & Summerfield	Oct - Dec 2009
RH #15	RH	159	89	11	0	72"	150ft NW of 5th Ave along Dean Street	Oct - Dec 2009
HP #16	HP	76	79	21	0	48"	50ft SE of Edson Ave along E 222nd Street	Nov - Dec 2010
WI #1	WI	84	92	3	5	62" X 96"	E 114 St and Pleasant Avenue	Nov - Dec 2010
JA #4	JA	73	60	40	0	66"	120 Ave, east of Francis Lewis Blvd	Nov - Dec 2010
26 #5	26	87	86	14	0	78" X 78.8"	On Flatlands Ave, upstream of Reg. 2	Aug - Oct 2010
PR #7	PR	239	44	52	4	63" X 94"	Targee St, SW of Glove Rd	Nov - Dec 2010
CI #14	CI	114	94	6	0	70" X 46.5"	Snyder Ave and Ralph Ave	Nov - Dec 2010
OH #15	OH	271	78	7	16	66"	West of Bay Parkway and 60th St	Nov - Dec 2010
OH #16	OH	185	89	11	0	64"	West of 4th Ave and 12 St	Nov - Dec 2010
JA #20	JA	367	83	9	9	87"	80th St and 95th Ave	Nov - Dec 2010
NR #22	NR	305	93	7	0	65.5"	W 96 St between Riverside Dr and W. End Ave	Nov - Dec 2010
JA #23	JA	13	84	16	0	42" X 57"	Hollis Ct Blvd between 93rd and 94th Ave	Nov - Dec 2010

3.2. Rainfall Events Used for Calibration/Validation

Monitoring of the flow and water depth was conducted in two phases. The first phase included sites that are located in the Bronx River, Flushing Bay, Newtown Creek and Gowanus Canal watersheds. This phase included the 10 sites in Tallman Island, Bowery Bay, Hunts Point, Newtown Creek, and Red Hook WWTP drainage areas as noted in Table 3-1 above. Metering in this phase lasted from October 20th to December 17th, 2009, and consisted of continuous measurement of depth and velocity in 5-minute intervals with flow being calculated at the same intervals. The remaining sites were monitored during the second phase which was from November 4th, 2010 to December 27th, 2010 except for the site in 26th Ward WWTP drainage area, which had 5-minute data available through a separate flow monitoring program conducted in another DEP project. Flow, depth and velocity data in 5-minute intervals were available at the 26th Ward site for the period between August 10th and October 18th, 2010.

Total rainfall depth, peak intensity, average intensity and the duration of the thirteen events are listed in Table 3-2a. Out of the six events selected for model calibration, two had a depth lower than 0.5 inches, two events were between 0.5 to 1 inch, and two were larger than 1 inch in total rainfall depth. Two of the seven events selected for validation were lower than 0.5 inches in rainfall depth, three were between 0.5 to 1 inch and two were larger than 1 inch. The maximum intensities of the rain events used for the calibration/validation varied from 0.02 to 0.56 inches per hour.

The second phase of the monitoring (November to December 2010) had different rainfall characteristics as it was relatively dry compared to the first monitoring period. Five events were selected for analysis, three for model calibration and two for model validation. Properties of the five events are tabulated in

Table 3-2b. One event had a total depth less than 0.2 inches, one was about 0.7 inches and the remaining three had total rainfall depths of about 1 inch.

Three model calibration and three validation events were selected for the 26th Ward site, as listed in Table 3-2c. The events were also representative of a wide range of rainfalls, with total volume varying from 0.47 to 2.02 inches, and maximum intensities varying from 0.10 to 1.14 inches per hour.

Table 3-2a Model Calibration and Validation Events for first phase Monitoring for Sites in Tallman Island, Hunts Point, Bowery Bay, Newtown Creek and Red Hook

Calibration/ Validation	Event Date	Starting Hour	Total Volume (in)	Average Intensity (in/hr)	Maximum Intensity (in/hr)	Event Duration (hours)
Calibration Event 1	10/23/2009	19	0.7	0.07	0.21	10
Validation Event 1	10/24/2009	10	1.3	0.1	0.56	10
Calibration Event 2	10/27/2009	6	0.39	0.04	0.09	10
Calibration Event 3	10/27/2009	21	1.52	0.08	0.16	19
Validation Event 2	10/31/2009	19	0.12	0.02	0.05	19
Calibration Event 4	11/12/2009	11	0.07	0.01	0.02	6
Validation Event 3	11/13/2009	21	0.55	0.02	0.21	21
Calibration Event 5	11/19/2009	21	0.65	0.07	0.32	10
Validation Event 4	11/30/2009	12	0.27	0.05	0.07	12
Validation Event 5	12/2/2009	18	1.14	0.1	0.25	18
Validation Event 6	12/5/2009	12	0.64	0.06	0.11	12
Calibration Event 6	12/9/2009	1	1.48	0.12	0.31	12
Validation Event 7	12/13/2009	12	0.95	0.11	0.19	12

Table 3-2b Model Calibration and Validation Events during Phase II Monitoring for Sites in Jamaica, Corny Island, Owls Head, Port Richmond, Wards Island and North River

Calibration/ Validation	Event Date	Starting Hour	Total Volume (in)	Average Intensity (in/hr)	Maximum Intensity (in/hr)	Event Duration (hours)
Validation Event 1	11/4/2010	4	0.97	0.03	0.12	28
Calibration Event 1	11/16/2010	4	0.05	0.02	0.02	3
	11/16/2010	21	0.72	0.07	0.26	10
Validation Event 2	11/25/2010	15	0.06	0.02	0.04	3
	11/26/2010	1	0.15	0.02	0.03	6
Calibration Event 2	12/1/2010	2	0.97	0.06	0.52	15
Calibration Event 3	12/12/2010	1	1.17	0.05	0.14	25

Table 3-2c Model Calibration and Validation Events for Phase II Monitoring for the Site in 26 Wards WWTP Drainage Area

Calibration/ Validation	Event Date	Starting Hour	Total Volume (in)	Average Intensity (in/hr)	Maximum Intensity (in/hr)	Event Duration (hours)
Validation Event 1	8/22/2010	12	1.36	0.34	1.14	4
Validation Event 2	8/25/2010	0	0.8	0.11	0.23	7
Validation Event 3	9/12/2010	12	0.47	0.08	0.1	6
Calibration Event 1	9/30/2010	4	1.02	0.2	0.67	5
Calibration Event 2	10/1/2010	3	2.02	0.18	1.1	11
Calibration Event 3	10/11/2010	18	0.7	0.09	0.36	8

Surface Categories for the North River Site

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 3-2

3.3. Model Calibration/Validation

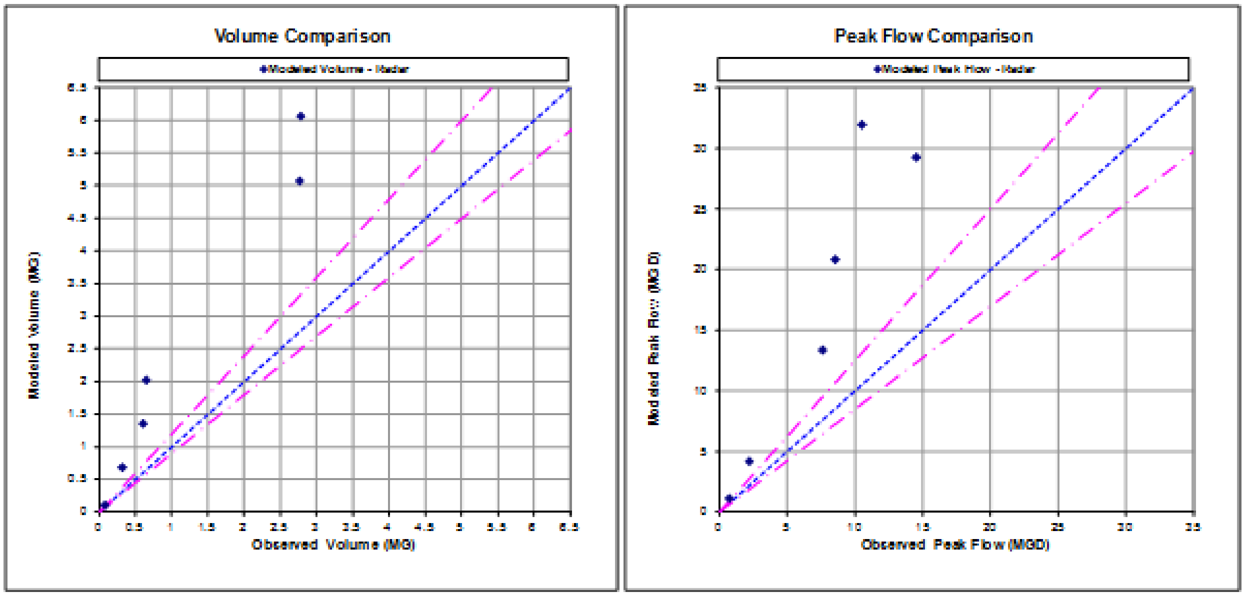
As discussed in Section 1, rainfall-runoff modeling parameters used in the DCIA method are: initial Loss or depression storage (DP), runoff coefficient (C), and roughness (N). DP is the initial rainfall loss (ponding) that needs to be filled before excess rain water generates runoff from the land surfaces. C represents the proportion of generated runoff volume that contributes flow to the sewer system. For the impervious areas, C represents the ratio of DCIA to the total impervious area. For pervious areas, it represents the fraction of runoff generated from these areas that eventually reach a sewer system.

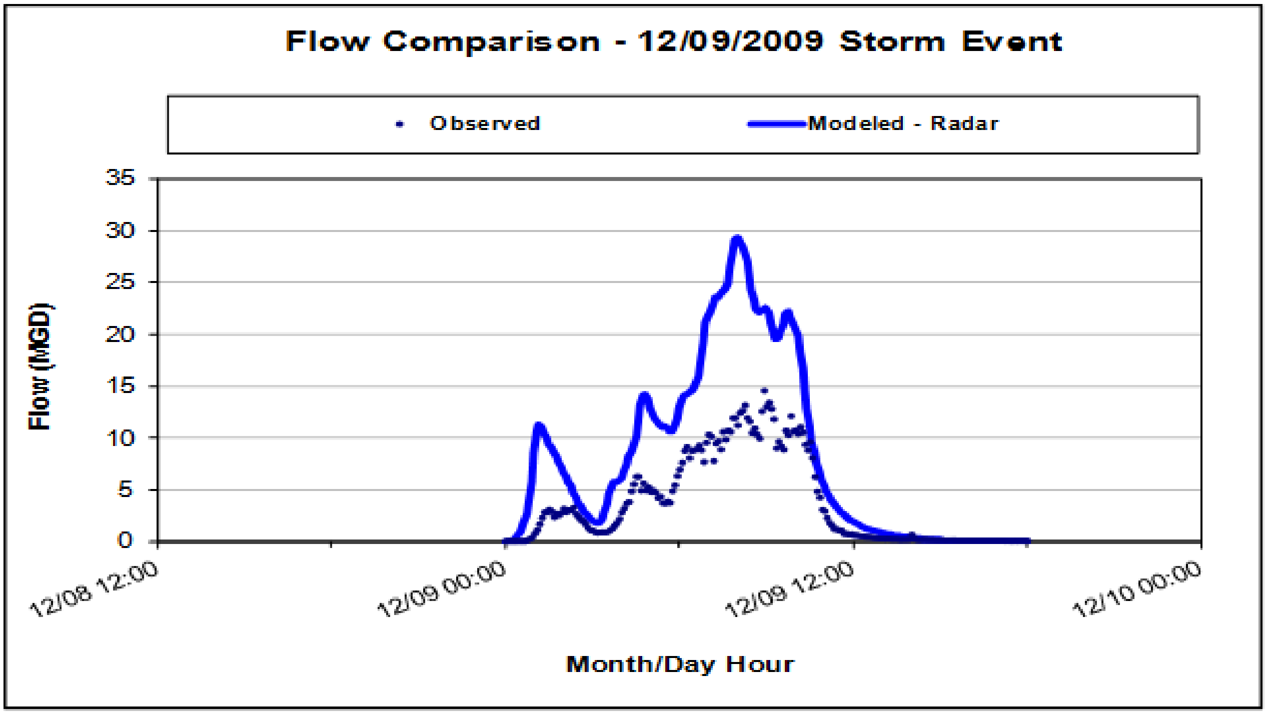
Roughness N, in conjunction with subcatchment slope and overland flow width, determines how fast runoff travels over the land surface, and therefore affects the peak flow and shape of the resulting runoff hydrograph. These parameters were estimated initially and adjusted during model calibration. The most important of these model parameters was the runoff coefficient, which controls the total amount of runoff. The initial estimate of the runoff coefficient was assumed to be 1.0 for both types of impervious surfaces, 0.4 for open pervious space and 0.2 for non-open pervious space.

The models were run in a continuous simulation mode for the entire monitoring period. Dry weather flow (DWF) originally derived from population estimates at each meter was adjusted to a minor extent to reflect the observed DWF rates before calibrating runoff during wet weather events. The results from the calibration events were used as the basis of adjusting model parameters. When the calibration goals were achieved, the parameters were applied to the validation events to see how the model performed for these independent set of events.

As noted earlier, the starting point for recalibration analysis was the assumption that the surfaces identified by Columbia University as impervious would all produce runoff (Runoff Coefficient “C” = 1.0) that entered the combined sewers. In all cases, the initial calibration results (examples shown in Figures 3-3 and 3-4) indicated that when the DCIA method was applied, the assumption that collection systems would receive 100% of the runoff generated from impervious land surfaces resulted in over-estimated runoff volumes and peak flows. An impervious area runoff coefficient less than 1.0 was subsequently found to provide a better estimate of the runoff generated on impervious surfaces. This was the foundation for our use of DCIA to represent the fraction of impervious area contributing direct runoff to the sewer system. Typical results of the site-scale calibration analyses are shown below for the Bowery Bay WWTP (Figure 3-3) and Owls Head WWTP (Figure 3-4) area site-scale metering locations. Similar results were found for all of the site-scale calibration analyses.

The final model calibration and validation plots and discussion are provided in Appendix A for each site. Table 3-3 summarizes the calibrated rainfall-runoff parameters. Overall, the site-scale model calibration and validation analyses suggested runoff values ranged from 0.45 or less to 0.80 (Table 3-3) would be appropriate depending on the subcatchment characteristics.

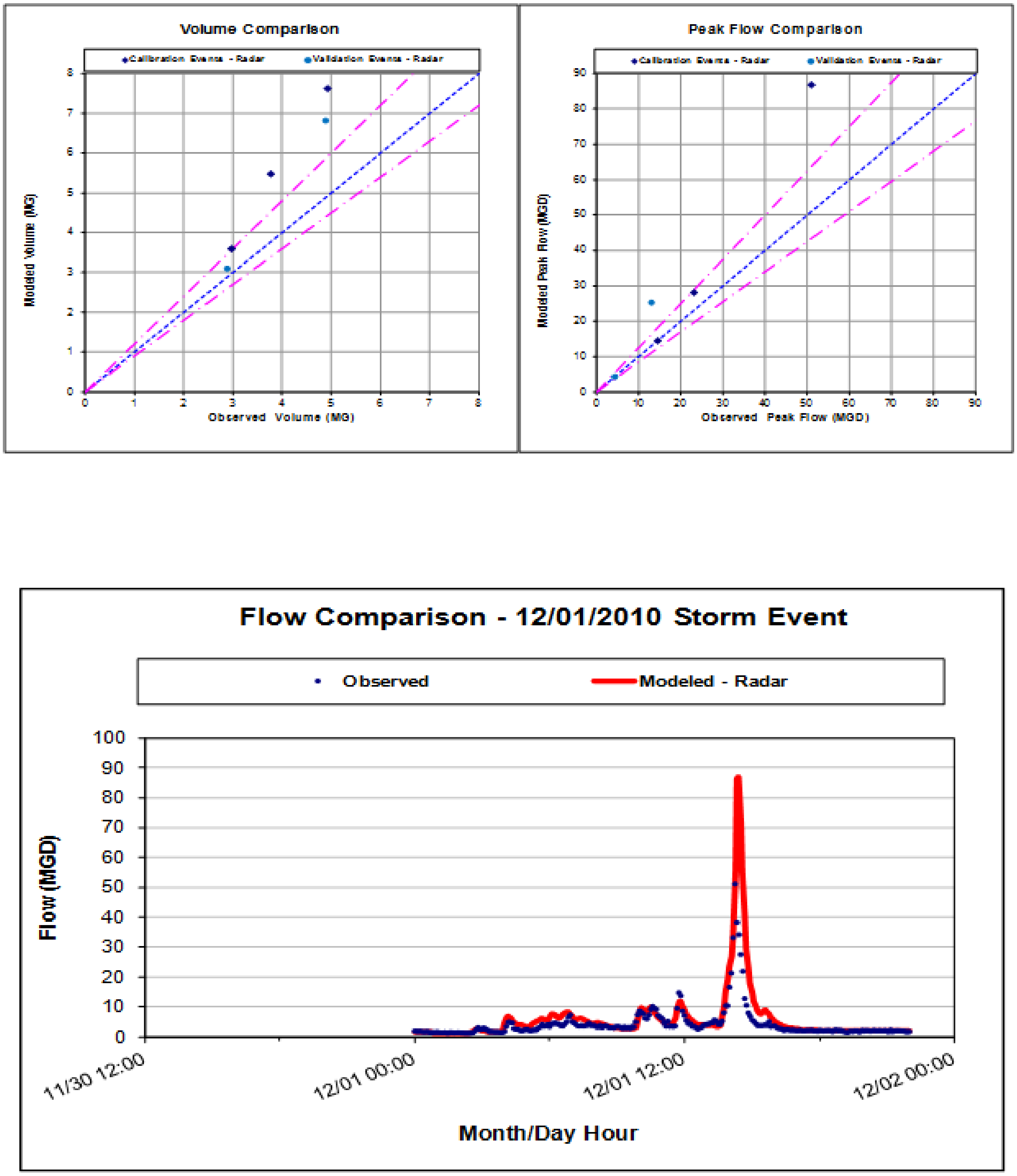




Initial Bowery Bay Site Calibration Results (C_{imp}=1.0)

NYCDEP Citywide InfoWorks Recalibration Report

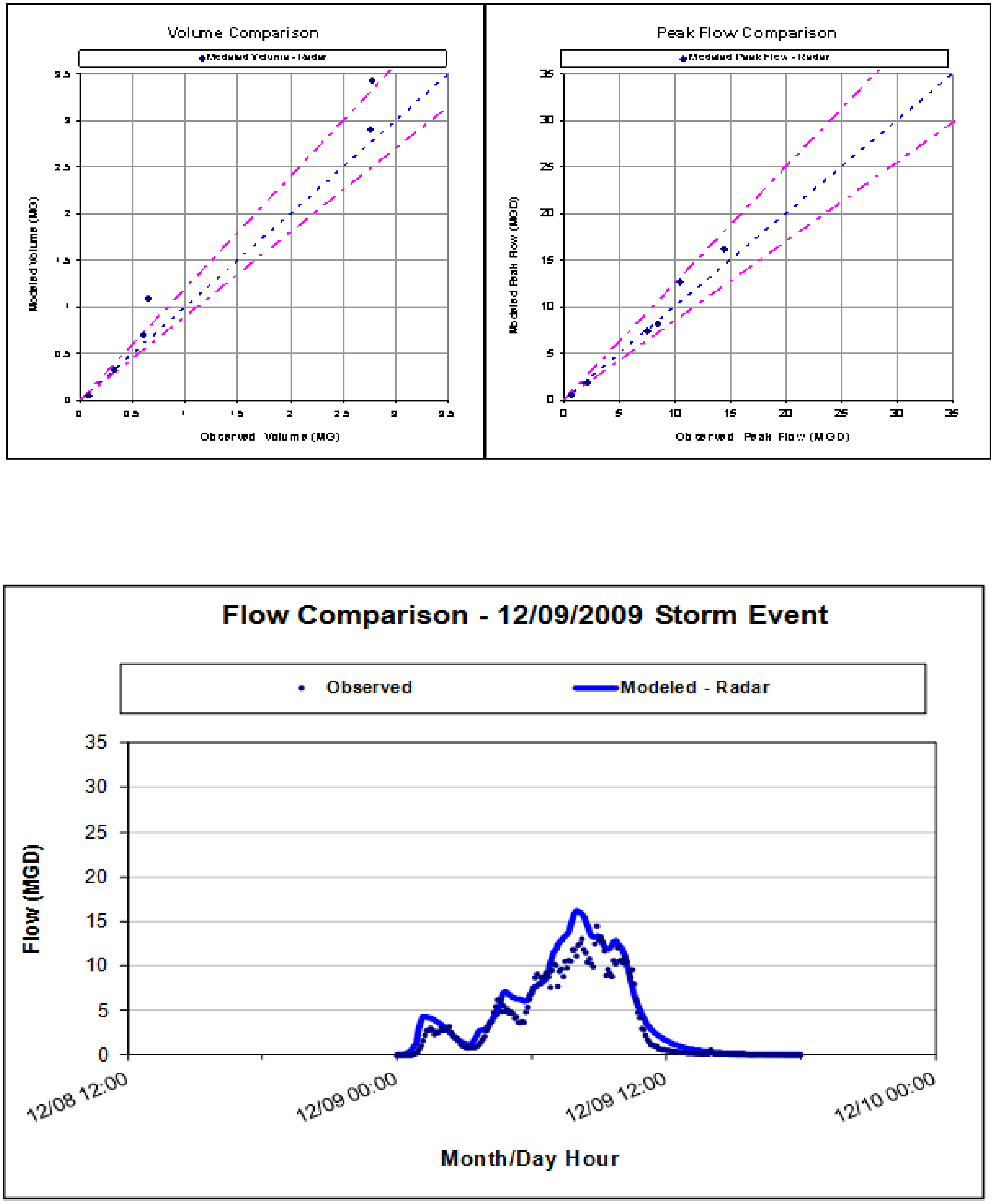
FIGURE 3-3



Initial Owls HeadSite Calibration Results (C_{imp}=1.0)

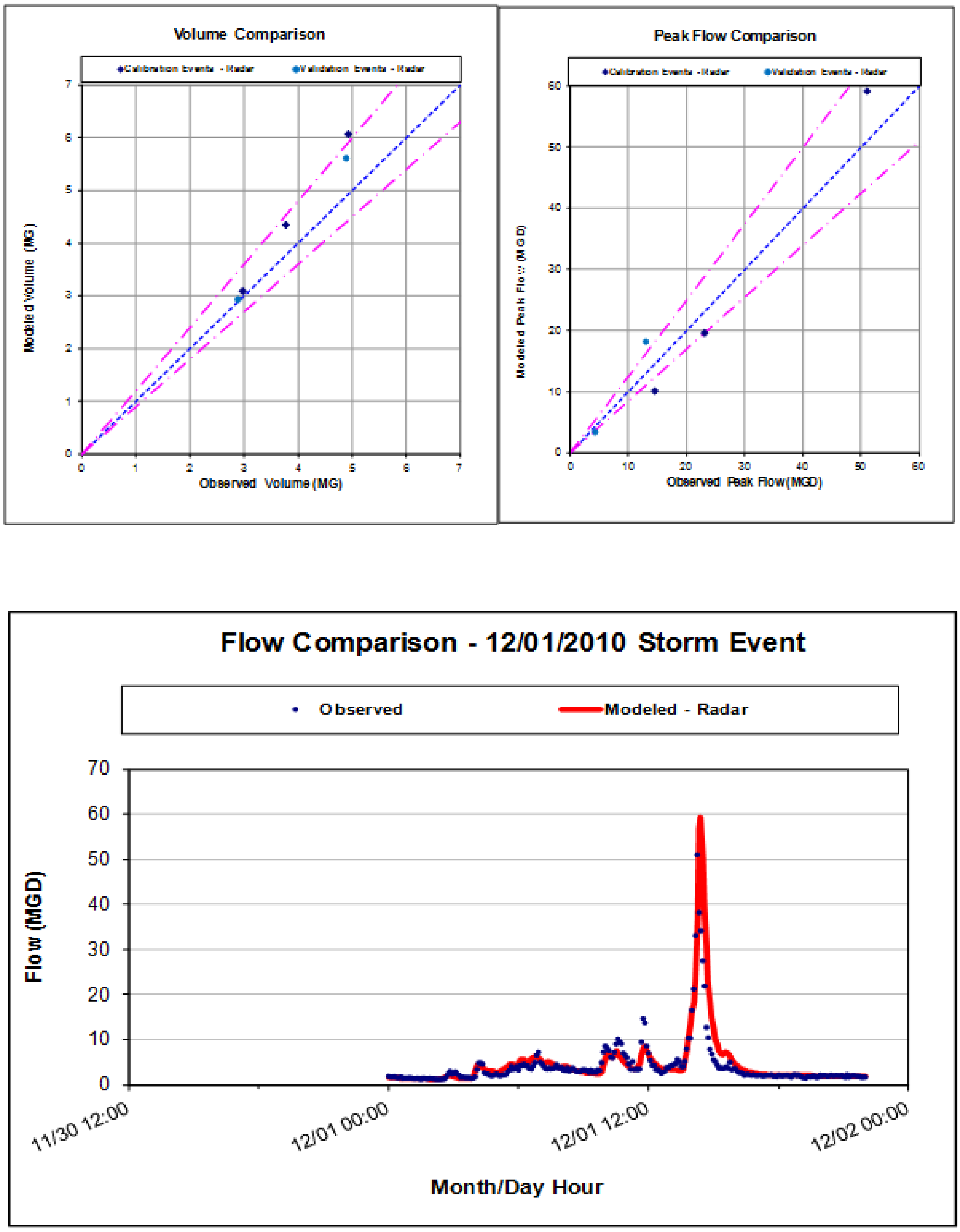
NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 3-4



Final Bowery Bay Site Calibration Results (C_{imp}=0.5)

NYCDEP Citywide InfoWorks Recalibration Report FIGURE 3-5



Final Owls Head Site Calibration Results (C_{imp}=0.7)

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 3-6

Table 3-3 Site-scale Calibration Hydrology Parameter Values

Site ID	WWTP	Runoff Coefficent C			Initial Loss DP (inches)			Roughness N		
		Impervious	Pervious- Non Open	Pervious - Open	Impervious	Pervious- Non Open	Pervious - Open	Impervious	Pervious- Non Open	Pervious Open
HP #10	HP	0.7	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
HP #12	HP	0.7	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
TI #1	TI	0.45	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
TI #2	TI	0.8	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
TI #3	TI	0.8	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
BB #13	BB	0.5	0.4	0.1	0.02	0.2	0.2	0.02	0.1	0.3
NC #6	NC	0.7	0.4	0.1	0.02	0.2	0.2	0.02	0.1	0.3
NC #7	NC	0.7	0.4	0.1	0.02	0.2	0.2	0.02	0.1	0.3
RH #15	RH	0.7	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
HP #16	HP	0.7	0.2	0.2	0.02	0.2	0.2	0.02	0.1	0.3
WI #1	WI	0.3	0.2	0.1	0.0042	0.0042	0.0042	0.01	0.05	0.15
JA #4	JA	0.55	0.35	0.1	0.02	0.2	0.2	0.01	0.05	0.15
26 #5	26	0.55	0.35	0.1	0.02	0.2	0.2	0.01	0.05	0.15
PR #7	PR	0.5	0.4	0.1	0.02	0.2	0.2	0.02	0.2	0.3
CI #14	CI	0.7	0.4	0.1	0.02	0.2	0.2	0.01	0.05	0.15
OH #15	OH	0.7	0.4	0.1	0.02	0.2	0.2	0.01	0.05	0.15
OH #16	OH	0.7	0.4	0.1	0.02	0.2	0.2	0.01	0.05	0.15
JA #20	JA	0.45	0.25	0.1	0.02	0.2	0.2	0.01	0.05	0.15
NR #22	NR	0.7	0.4	0.1	0.02	0.2	0.2	0.02	0.2	0.3
JA #23	JA	1	0.6	0.1	0.02	0.2	0.2	0.01	0.05	0.15

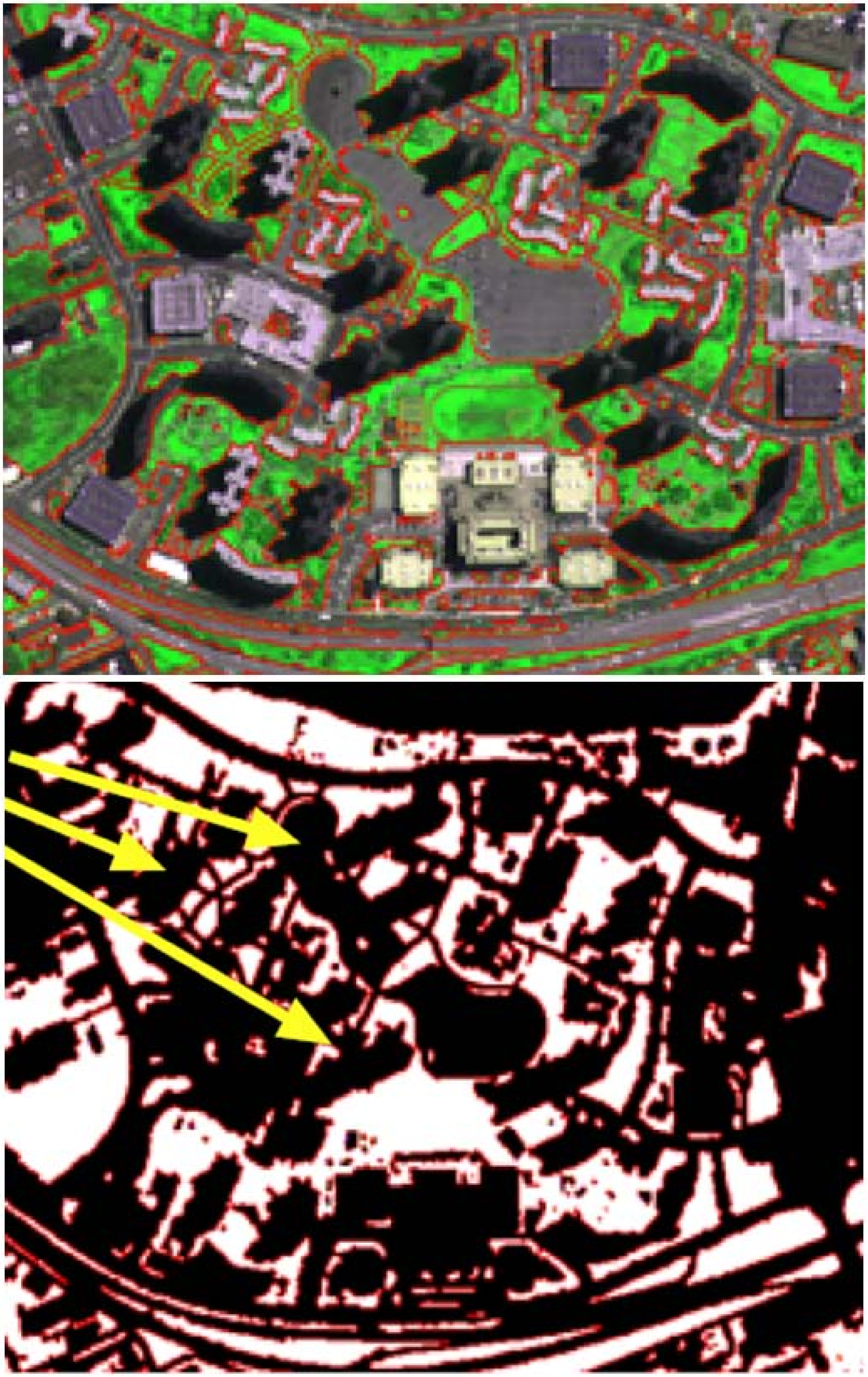
As seen in Table 3-3 above, the calibrated runoff coefficients for pervious non-open areas ranged from 0.2 to 0.4 (excluding the Jamaica site that is affected by seepage pits within the service area). For pervious open surfaces, calibrated runoff coefficients ranged from 0.1 to 0.2. The results indicate that, on average, 60% to 80% of the rain generated from non-open pervious land and 80% to 90% from pervious open spaces does not reach the sewer systems, but is lost through infiltration or other means. Calibrated runoff coefficients for impervious surfaces fell within a range of 0.45 to 0.80, indicating that about 20% to 55% of the runoff generated on impervious surfaces does not reach the collection system.

It should be noted that the runoff coefficient for the impervious areas less than one can be thought of as containing two separate and distinct items. One item being that not all of the surfaces identified by the satellite imagery analysis are directly connected to the sewer system and result in generation of runoff that will enter the system. The second item is the fact that the satellite imagery analysis could and does have errors contained within it and should not be considered as being 100 percent accurate. Spectral densities are first interpreted using a mathematical model applied on multiple test areas with unique land features, and is then extended on a city-wide scale to estimate the extent of pervious areas. It is quite possible that those errors are in the direction of over-estimating the impervious surface area. A number of errors were found to exist upon close examination of the imagery results, such as:

- Shadows – Figure 3-7 provides an example where shadows appear in the image taken by the satellite adjacent to high-rise buildings. The left image is the Columbia University interpretation of signals received by the satellite with the white areas being pervious and the black areas being impervious. Comparing the left image to the one on the right shows shadows as being detected as impervious surfaces when portions of them clearly fall over lawn areas. This is a clear case where the analysis methodology would lead to an over-estimate of the impervious surfaces.

- Dry Surfaces – Figure 3-8 shows an area of the Bronx (Jerome Park Reservoir) where it appears that the analysis was unable to identify an area that is likely somewhat pervious because of the reflective image that it was giving off. In the image on the left, the large black area (impervious) is clearly a portion of the reservoir that could be pervious but is showing up in the analysis as impervious.

We have incorporated this uncertainty in imperviousness estimates and implications on model results through a sensitivity analysis discussed in Section 5 of this report.



Example of Shadow Error for Overestimates of Impervious Surface

FIGURE 3-7

NYCDEP Citywide InfoWorks Recalibration Report

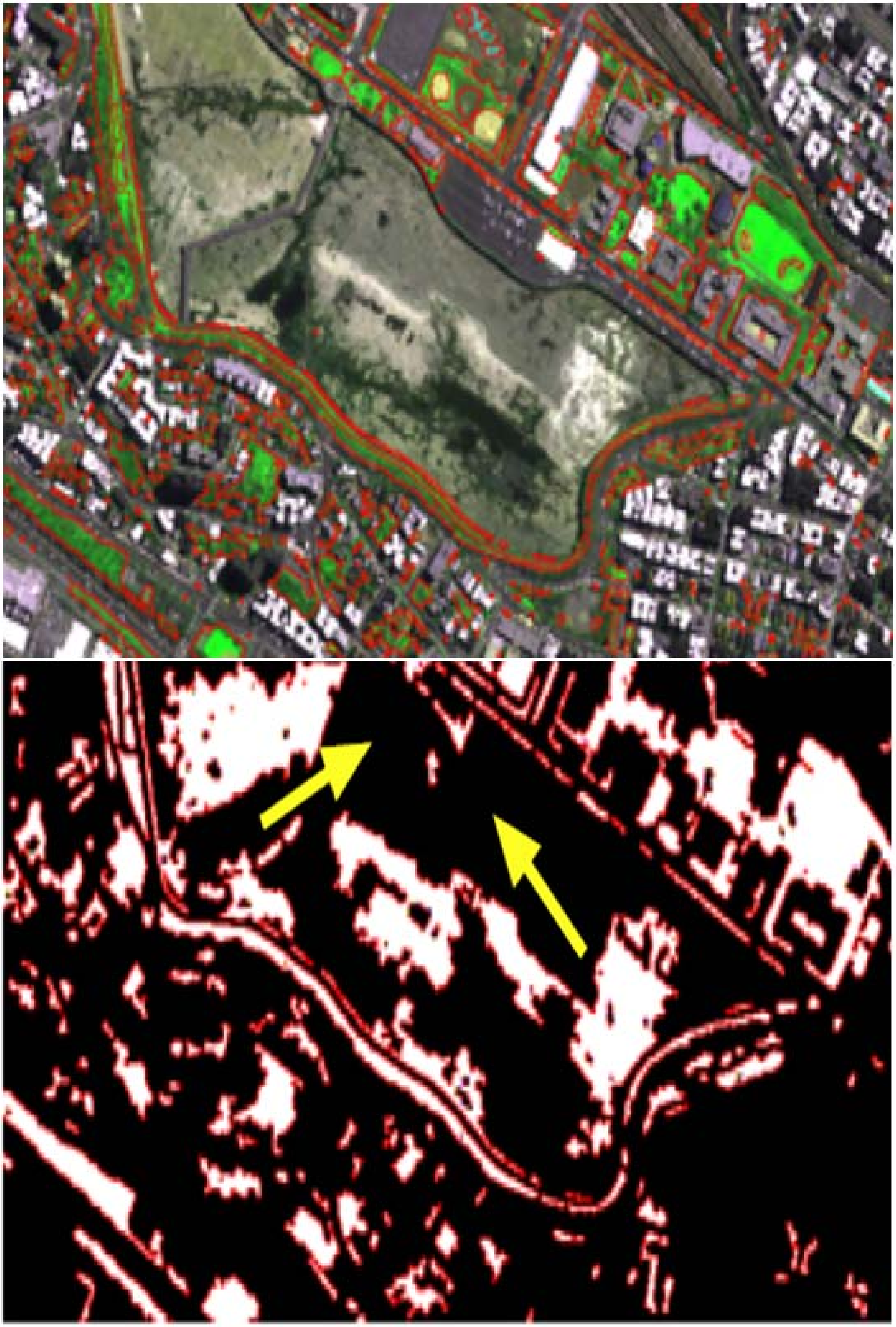


FIGURE 3-8

Example of Dry Surfaces Error for Overestimates of Impervious Surface

NYCDEP Citywide InfoWorks Recalibration Report

It is not important to distinguish between the causes for the revisions being made for the purpose of modeling; however, the total DCIA is relatively important for the purposes of planning for green infrastructure and developing an approach for locating such runoff management systems. For that explicit purpose it is safe to assume that the total DCIA in any subcatchment would be the product of the Columbia University impervious area and the impervious area runoff coefficient ("C") developed herein.

3.4. Hydrology Parameter Generalization

A major objective of the site-scale calibration was to develop a set of hydrology parameters that could be applied globally to the area-wide models. As part of the analysis, relationships were examined between runoff coefficients and characteristics of the metered drainage areas, such as the size of the drainage area, percent imperviousness, land use (single family residential, multi- family residential, industrial, etc.) in an attempt to generalize the parameters.

The analysis indicated that the percentage of a subcatchment covered by single family homes would be a good indicator of the level of urbanization, population density, and even the hydrology characteristics of the pervious areas. The ratio of single family lots to connected subcatchment area exclusive of open spaces like parks and cemeteries was calculated for all sites. The Single Family Ratios (SFR) are shown along with their runoff coefficients in Figure 2-9. Subcatchments colored white have a SFR ratio less than 0.2. These areas are highly urbanized; their residential areas are dominated by high- and low-rise apartment buildings or other commercial or industrial land uses. Additionally, these areas generally are less pervious and the pervious areas are more scattered and with more compacted soils. The blue colored subcatchments have SFR larger than 0.2. The darker the blue color, the higher the SFR and the less urbanized and populated these subcatchments are. These areas generally have a larger proportion of pervious areas, with less compacted soils and better infiltration.

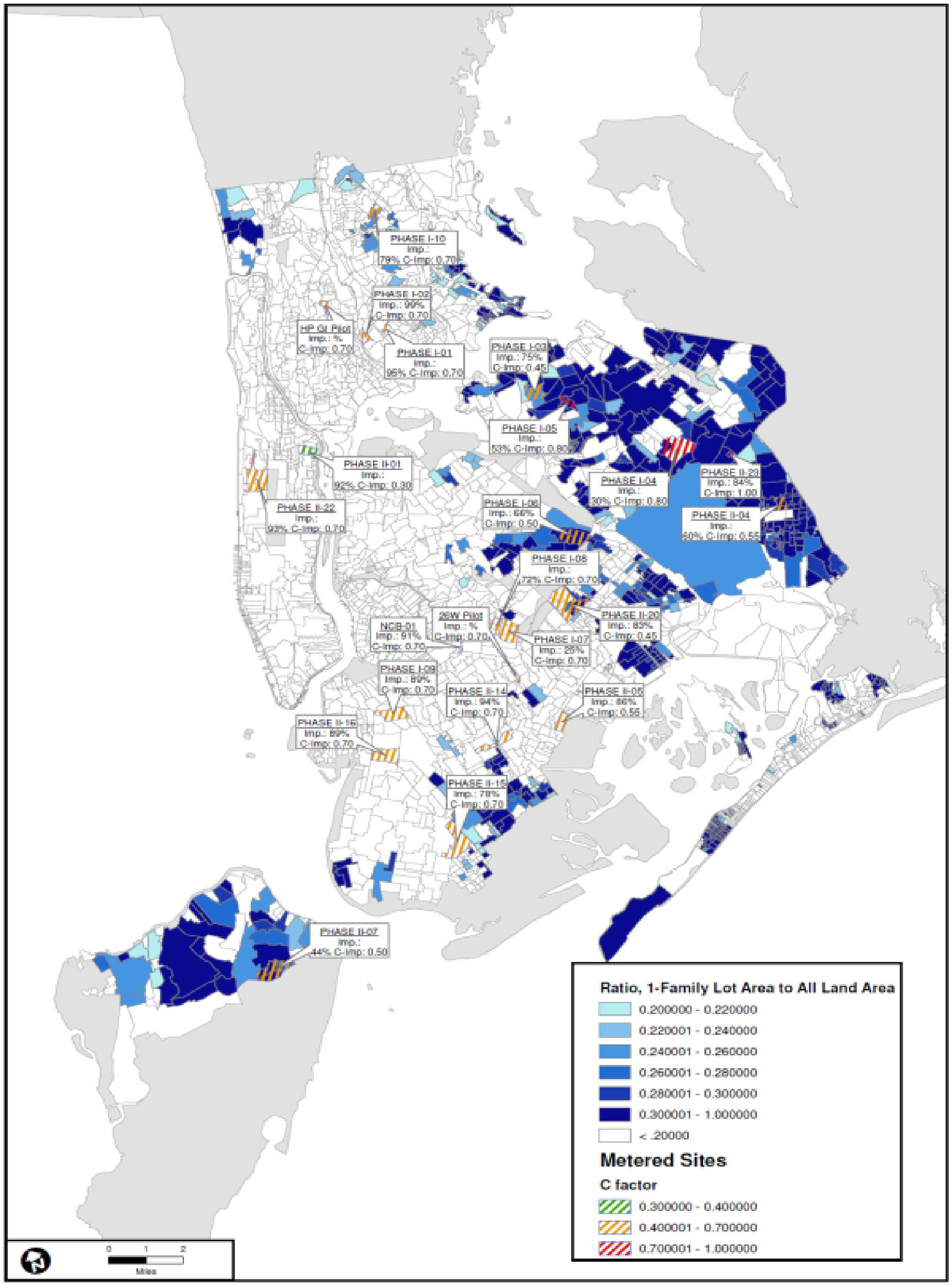
The correlation between SFR and runoff coefficients for the 20 sites are shown in Figure 2-10. The highlighted outlier with a runoff coefficient of 1.0 was used in the Jamaica service area where there were an abundance of seepage pits that complicated the ability to truly define the subcatchment boundary. The outlier with a runoff coefficient of 0.3 was the Wards Island site, where a number of unknown interconnections existed. As discussed in Appendix A for the Jamaica and Wards Island WWTP areas, both of the sites had a high level of uncertainty on the size of the metered drainage areas, and therefore they were excluded from this particular analysis. Figure 2-9 shows that except for the highlighted TI site, the remaining sites that have low SFR generally have higher impervious surface runoff coefficients in the range of 0.6 to 0.8; with many equal to 0.7. The sites with high SFR appear to be less hydraulically connected with runoff coefficients in the range of 0.4 to 0.6. Based on the above analysis, a runoff coefficient of 0.7 was selected for subcatchments with a SFR equal or less than 0.25 and 0.5 was selected for subcatchments with a SFR larger than 0.25.

Table 3-4 summarizes the final generalized hydrology parameters from the site-scale calibration. These parameters were used as the initial parameters when the revised DCIA modeling method was scaled-up to the area-wide models.

Table 3-4 Summary of Generalized Hydrology Parameters from Site-Scale Calibration.

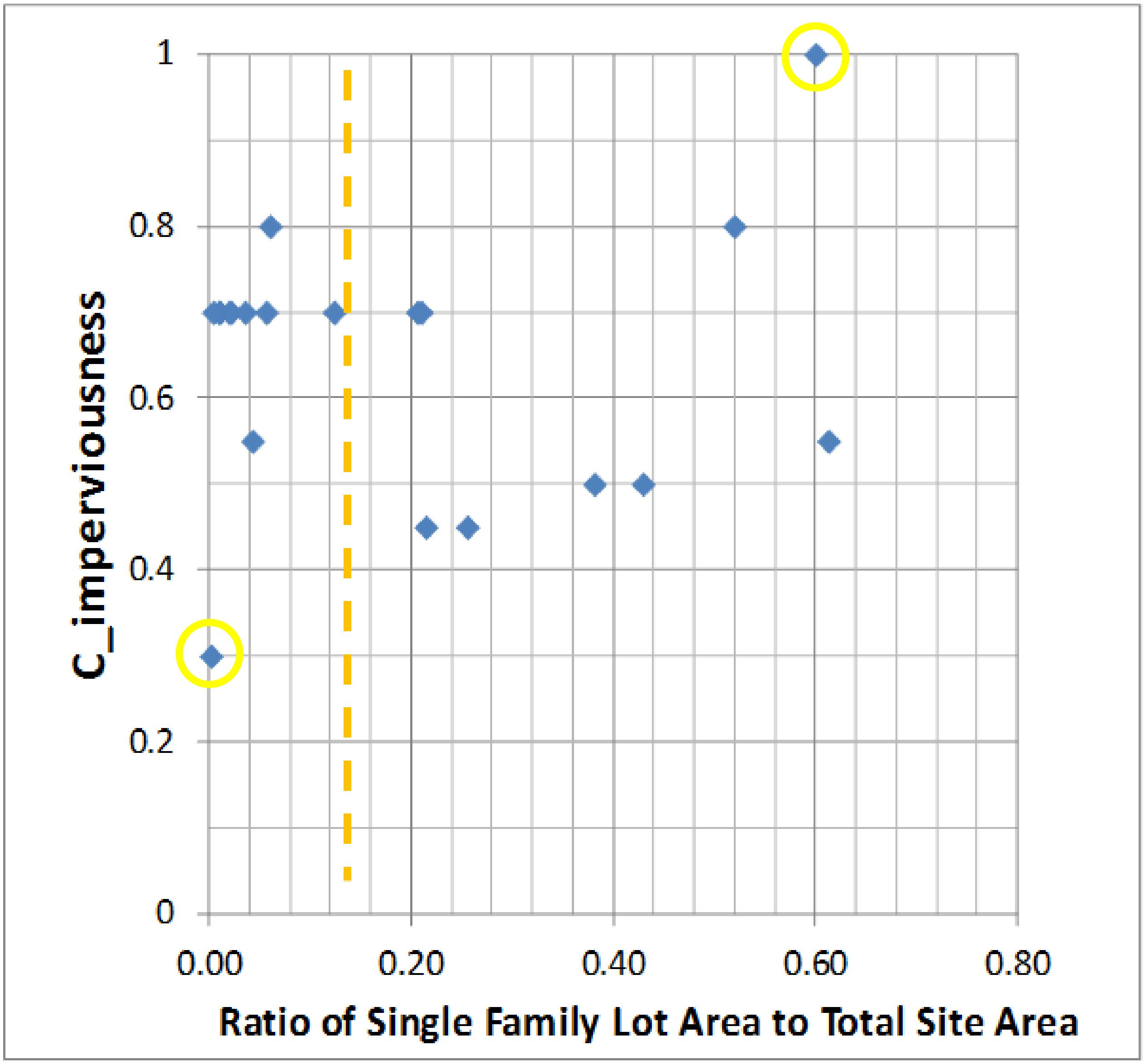
Surface Type			Parameters		
			Initial Loss (inch)	Runoff Coefficient	Roughness
Impervious	**SFR <=0.25**	**No DP(25%)**	0	0.7	0.01
		with DP(75%)	0.02	0.7	0.01
	SFR >0.25	**No DP(25%)**	0	0.5	0.01
		with DP(75%)	0.02	0.5	0.01
Pervious	**Non Open**		0.2	0.4	0.05
	Open		0.2	0.1	0.15

In the method used to develop the 2007 LTCP models, most of the models were assumed to have 100% of the runoff from impervious surfaces received by the collection systems, and infiltration functions were used to control the rates of runoff. As a result, little runoff from pervious surfaces was generated for most small and moderate rain storms. The DCIA method showed *pervious* surfaces contributing 10 to 40% of the runoff for all storms larger than the initial rainfall loss. Using a runoff coefficient of less than 1 (100% connected) for the *impervious* surfaces proved to be reasonable.



Map of Single Family Lot to Subcatchment Area Ratio for NYC Drainage Areas

NYCDEP Citywide InfoWorks Recalibration Report FIGURE 3-9



Correlation Between SFRs and Runoff Coefficients for 20 Site-scale Sites

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 3-10

Section 4.0

Area-wide Calibration

4.1. Recalibration Approach

Model parameters developed during site-scale calibration, based on estimates of pervious areas using satellite imagery data and the use of DCIA methodology, were extended to the full-scale area-wide WWTP drainage area models. As the IW model areas are between 10,000 and 20,000 acres, the drainage areas were modeled using hundreds of small subcatchments. Parameters developed during site-scale calibration were applied globally to the WWTP drainage areas to assess the model performance on a watershed basis. The models were then recalibrated (which resulted in a testing and refinement of the original site-scale parameters) using event-based historical data available at various locations within the collection systems (where flow meters had been installed previously during WWFP development or other DEP projects), and also using 2011 flow data available at the WWTPs. All analyses conducted herein were performed using IW version 10.5, an updated version from those previously used for the 2007 WWFP modeling efforts.

4.2. Model Updates

Columbia University Impervious Cover Study

Area-wide models were first updated using the Columbia University satellite imagery data. For each modeled subcatchment identified as “combined”, “storm”, or “other” type, the imagery data in conjunction with PLUTO (quote the source here!!) land use data were used to estimate the proportion of the surface types discussed in Section 3, namely: impervious, pervious non-open and pervious open. Table 4-1 summarizes the percentages of total impervious, pervious non-open and pervious open areas in all 13 WWTP drainage areas. The percentage of imperviousness ranges from approximately 50% in Port Richmond to 90% in Red Hook. The subcatchments with SFR no larger than 0.25 received an initial impervious runoff coefficient (C) of 0.70, while the subcatchments with SFR ratios larger than 0.25 were assigned an initial C of 0.50, according to the global parameters developed during site-scale calibrations presented in Table 3-4.

Table 4-1 WWTP Drainage Area Impervious and Pervious Percentage Summary

WWTP	Total Area Where DCIA Method Applied (Acres)	Drainage Area Sufaces		
		% Impervious	% Pervious-Non Open	% Pervious - Open
26W	5,581	77.6	14.9	7.4
BB	12,446	87.1	9.7	3.2
CI	7,090	83.0	10.3	6.6
HP	17,940	68.5	14.3	17.3
JA	26,741	70.5	25.7	3.8
NC	13,599	86.5	6.2	7.2
NR	4,791	87.3	4.2	8.5
OH	8,723	85.9	7.2	6.9
PR	5,013	48.9	45.4	5.8
RH	2,991	90.2	1.1	8.7
RK	3,286	69.5	28.1	2.4
TI	11,180	66.0	25.3	8.7
WI	11,602	82.7	10.8	6.5

GIS Aligned Model Networks - The City's original WWTP drainage area models were historically developed (pre-2007) using different modeling software such as EPA SWMM, XP-SWMM, and HydroWorks. The models were all converted to IW during development of the WWFPs (2007). The modeled manholes and sewers correctly represented the hydraulic connectivity of the collection systems, but their locations were approximate, as they were estimated based on paper sewer I&I maps or background images. During 2010, efforts were taken to adjust the locations of modeled manholes and sewers to align them better with the underlying street layers and DEP-provided interceptor GIS information. These geo-referenced model networks have now been incorporated as part of the recalibration effort described in this report

Interceptor Sediment and Cleaning Data - Average sediment depths from DEP GIS data were applied uniformly to the corresponding model conduits. These sediments were used for all modeling simulations performed herein for the periods prior to 2011. For the 2011 simulations, interceptor sediment data reflected the results of sewer cleaning performed in the TI and JA WWTP drainage areas.

4.3. Event-Based Model Calibration

The updated area-wide models were calibrated using historical data available on an event basis to assess model performance using the DCIA methodology and revised impervious/pervious cover information.

Selected storm events from the in-system flow monitoring performed during and prior to the development of WWFPs and documented in the October 2007 reports were used here as the basis for area-wide model recalibration. For the BB High Level, TI, JA, and 26W WWTP drainage areas the latest available monitoring data were used for model calibration. Table 4-2 summarizes the monitoring periods, the number of meters used, and the types of data available for each WWTP drainage area. Flow meters with poor quality data were not included in the analysis. As seen in Table 4-2, the data availability varies between areas. Some drainage areas, such as the NC-Brooklyn, HP and BB WWTP drainage areas had a large number of locations where in-system monitoring data were available, both in the regulated portions of the conveyance system and in upstream areas. Other areas such as RH and NC-Manhattan only had a limited number of meters.

Since many of the earlier modeling efforts focused on characterizing flows in interceptors, large sewers and major regulators, much of the historical flow metering locations were in-system meters. Therefore, the flow behavior at the metered location does not reflect isolated hydrology behavior but is influenced by hydraulics in the collection system. Locations of the meters for each drainage area, along with the details of events used for calibration/validation, are shown in Appendix B of this report.

Table 4-2 Summary of Available Rainfall and Monitored Hydraulic Data for Each WWTP Drainage Area

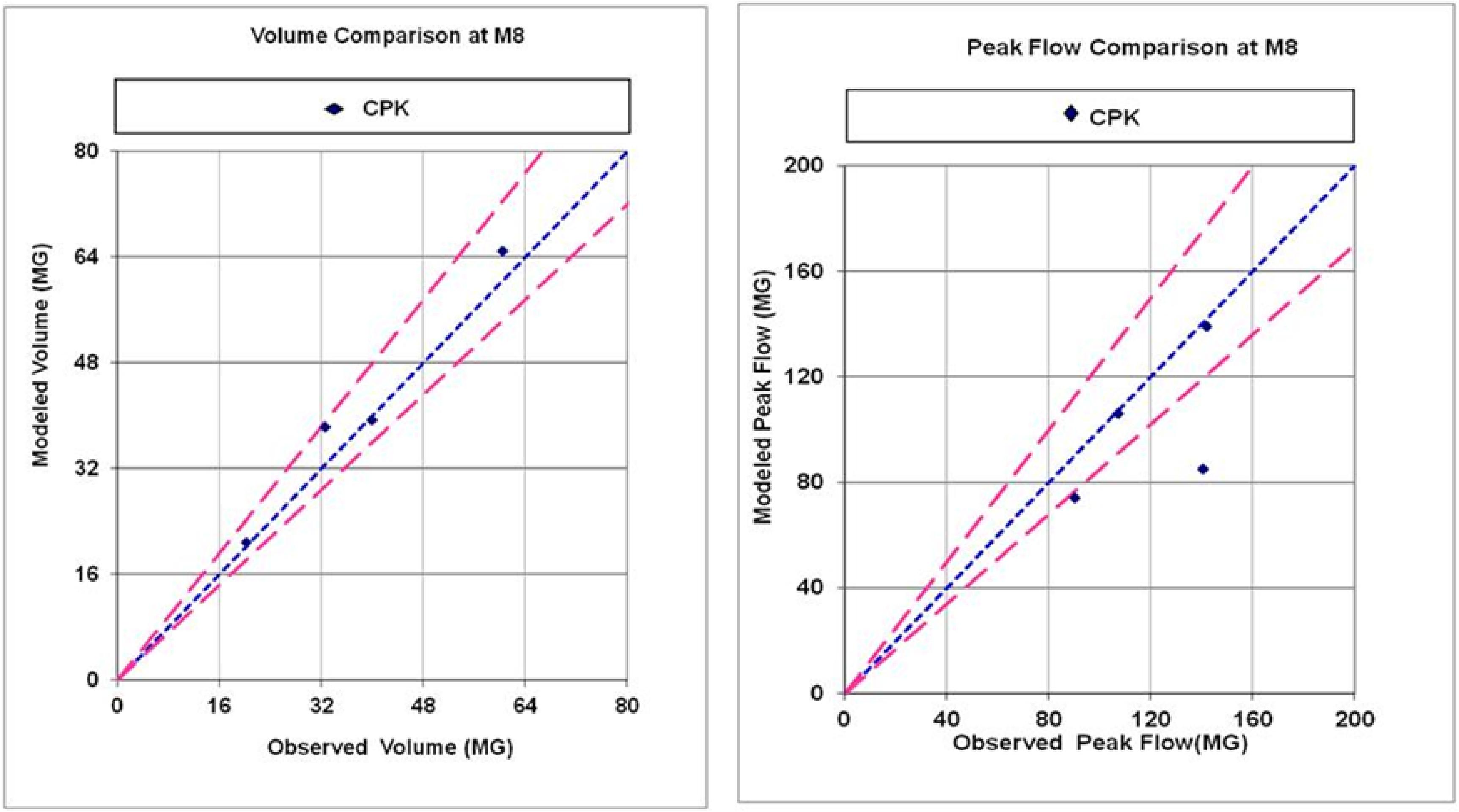
WWTP	Monitoring Periods	Number of Meters			Type of Data	Number of Calibration Events	Rain Data	
		In-system	Upland	Total			Rain Gage	Data Interval
26	August 16, 2010 to October 18, 2010	12	1	13	Flow, Depth, and Velocity	6	Local	5 min
BB	July to October 2005	5	5	10	Flow/Depth	4	Radar	15-min
CI	July to October 2005	2	1	3	Flow/Depth	4	Radar	15-min
HP	December 14, 2004 to January 13, 2005	14	0	14	Flow, Depth, and Velocity	5	LGA	hourly
JA	May 17, 2000 to August 30, 2000	13	2	15	Flow, Depth, and Velocity	4	JFK	5 min
NCM	July-October, 1995 and December-January, 1996	6	6	12	Depth	4	CPK	Houly
NCB	December 2005 to January 2006	5	7	12	Flow/Depth	4	CPK	Hourly
NR	April 2003 to November 2003	10	0	10	Flow	3	CPK	1 hour
OH	November 1996 to December 1996	10	0	10	Flow, Depth, and Velocity	3	JFK	hourly
							Local	15 min
PR	October to November 1997	4	0	4	Flow, Depth	1	EWR	1 hour
	September 2004	1	0	1	Depth	1	CPK	1 hour
	October 2005	1	0	1	Depth	1	JFK	1 hour
RH	August, 1995 to January, 1996	6	6	12	15-min Depth	3	CPK/JFK	Hourly
	October, 2001 to January, 2002	1		1	5-min Flow			
	April, 2003 to May, 2003	2	3	5	15-min Flow/Depth			
RO	August 2005 to November 2005	11	0	11	Flow, Depth, Velocity	1	Local	5 min
TI	July to October, 2005	1	5	6	5-min Flow	6	Radar	5-min
	June to July, 2008	5	0	5	15-min Depth	4	Radar	5-min
	March to May, 2010	N/A	N/A	7	Flow/Depth	5	LGA/CPK	hourly
WI	February 3, 2003 to June 30, 2003	2	0	2	Flow and Depth	7	Local	15 min
	July 5, 2005 to September 9	8	1	9	Flow and Depth	3	Local	5 min

Each of the individual WWTP drainage area IW models were run for selected calibration events using the available rainfall data presented in Table 4-2. Tidal boundary conditions for the same period at CSO outfalls were developed using the tidal program described in Section 2. The dry weather flows developed and documented in the October 2007 reports were used here. These sanitary sewage flows were generally based on the year 2000 population distribution in each model and per-capita wastewater generation rates developed from the WWTP influent flow data with hourly diurnal patterns imposed on them.

The hydrology parameters developed during the site-scale calibration were adjusted on an area-wide basis, when appropriate, to achieve better representation of the runoff generated at the upstream meters. Model input parameters that affect hydraulics of the models such as pipe roughness, local sediment levels, and throttling conditions at the plant were also modified within acceptable ranges.

Similar to the site-scale model calibrations, goodness-of-fit plots comparing modeled and observed volumes and peak flow rates were generated for assessment of model performance. Time-series comparisons (hydrographs) were also used to compare model simulation results. The plots for each WWTP drainage area are included in Appendix B.

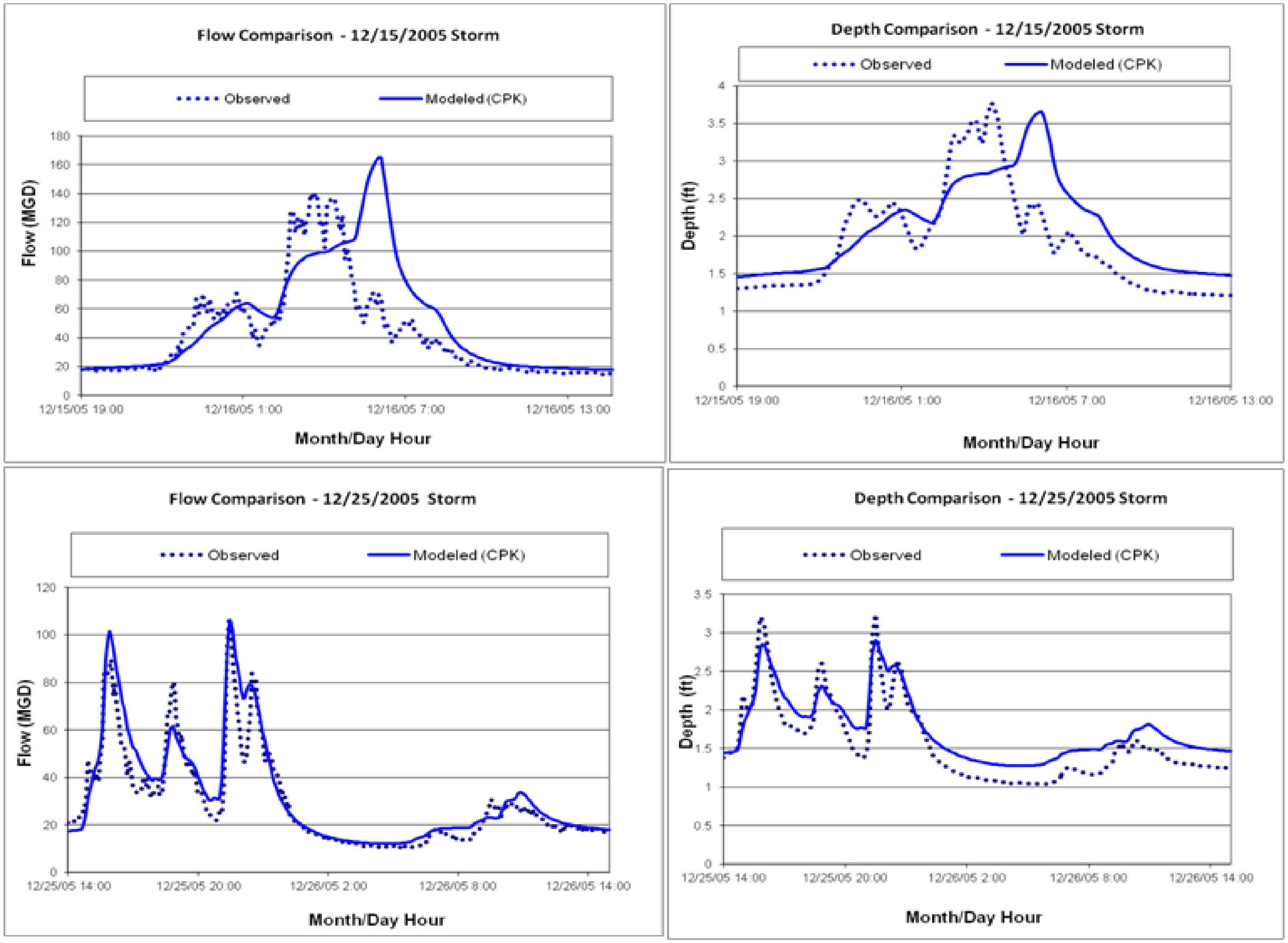
An example of the area-wide recalibration results for an upstream flow monitoring location (M8) is provided in Figure 4-1. This location is the inflow to a regulator (NC-B03) in the NC WWTP drainage area in Brooklyn. These graphics (Figures 4-2a and 4-2b) provide the resulting goodness-of-fit comparisons for model results and observed flow monitoring data. For the model simulations, hourly Central Park rainfall data were used in the models. Overall, the goodness-of-fit for the NC – Brooklyn flow and volume comparisons indicated good agreement between modeled and observed data, and thus no additional changes to the global parameters were employed in the model.



Area-Wide Recalibration Results for an Upstream Flow Monitoring Location (M8)

NYCDEP Citywide InfoWorks Recalibration Report

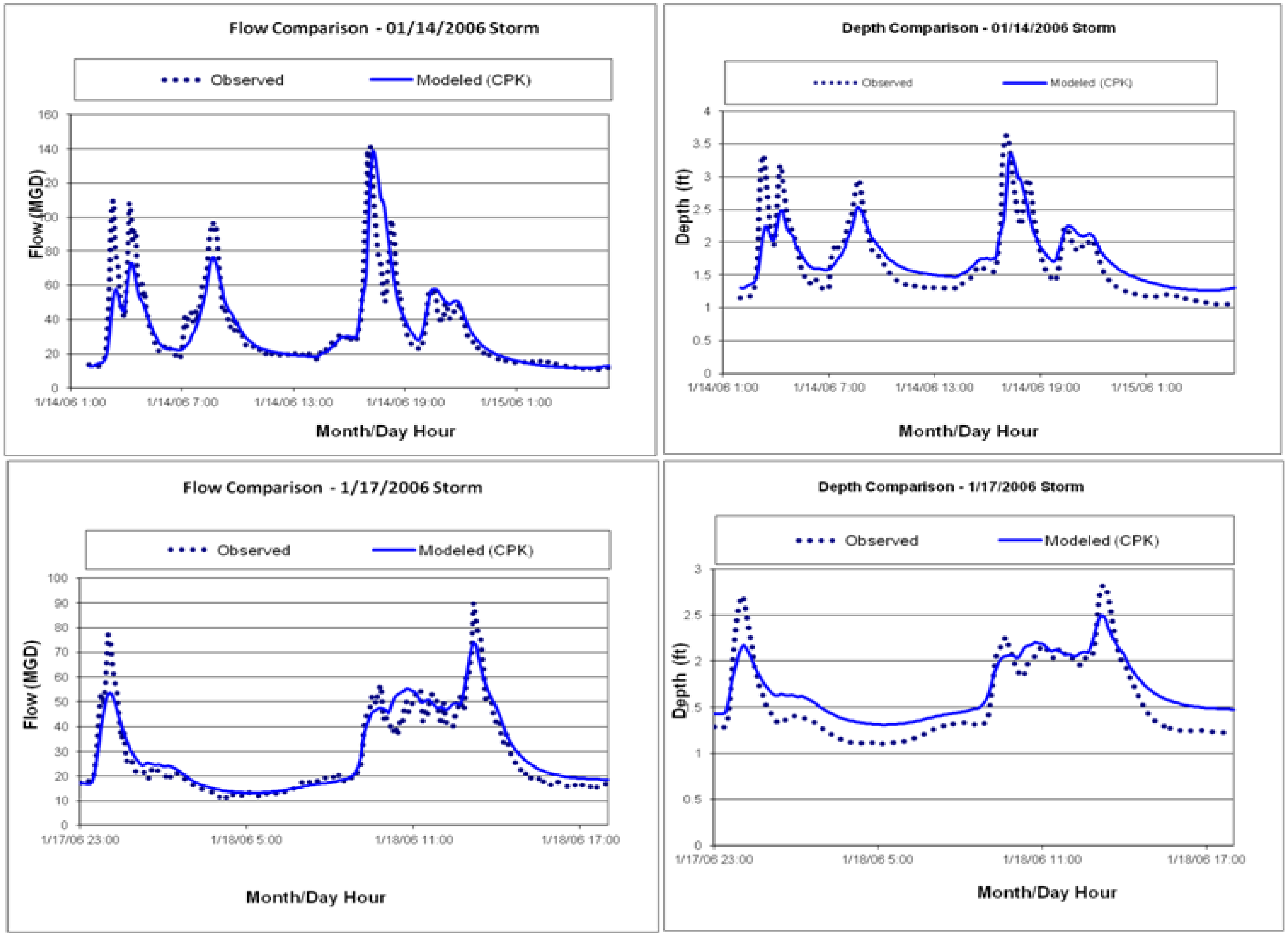
FIGURE 4-1



Goodness of Fit Comparisons 2005 in Brooklyn (NC-B03)

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 4-2a

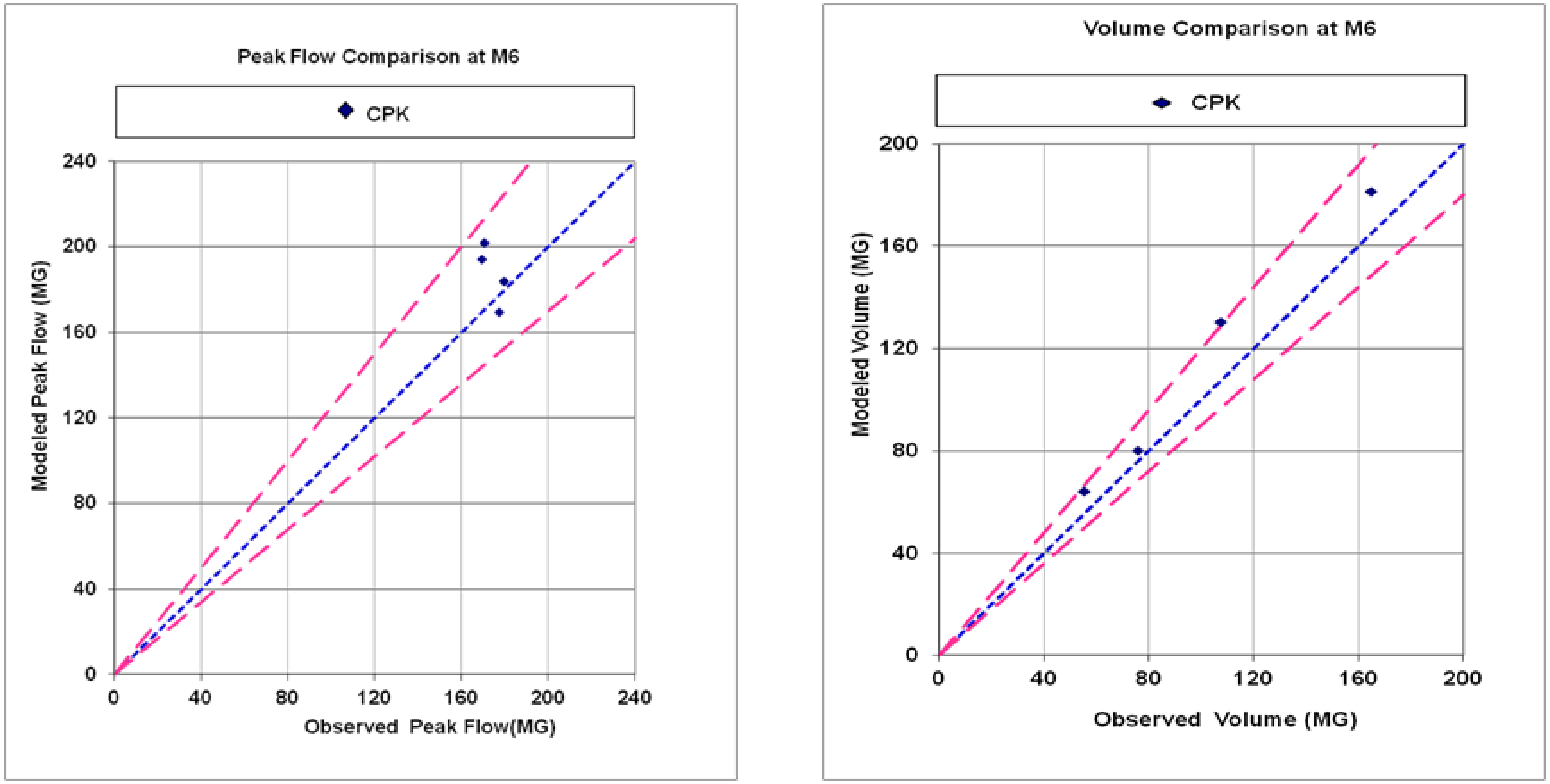


Goodness of Fit Comparisons 2006 in Brooklyn (NC-B03)

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 4-2b

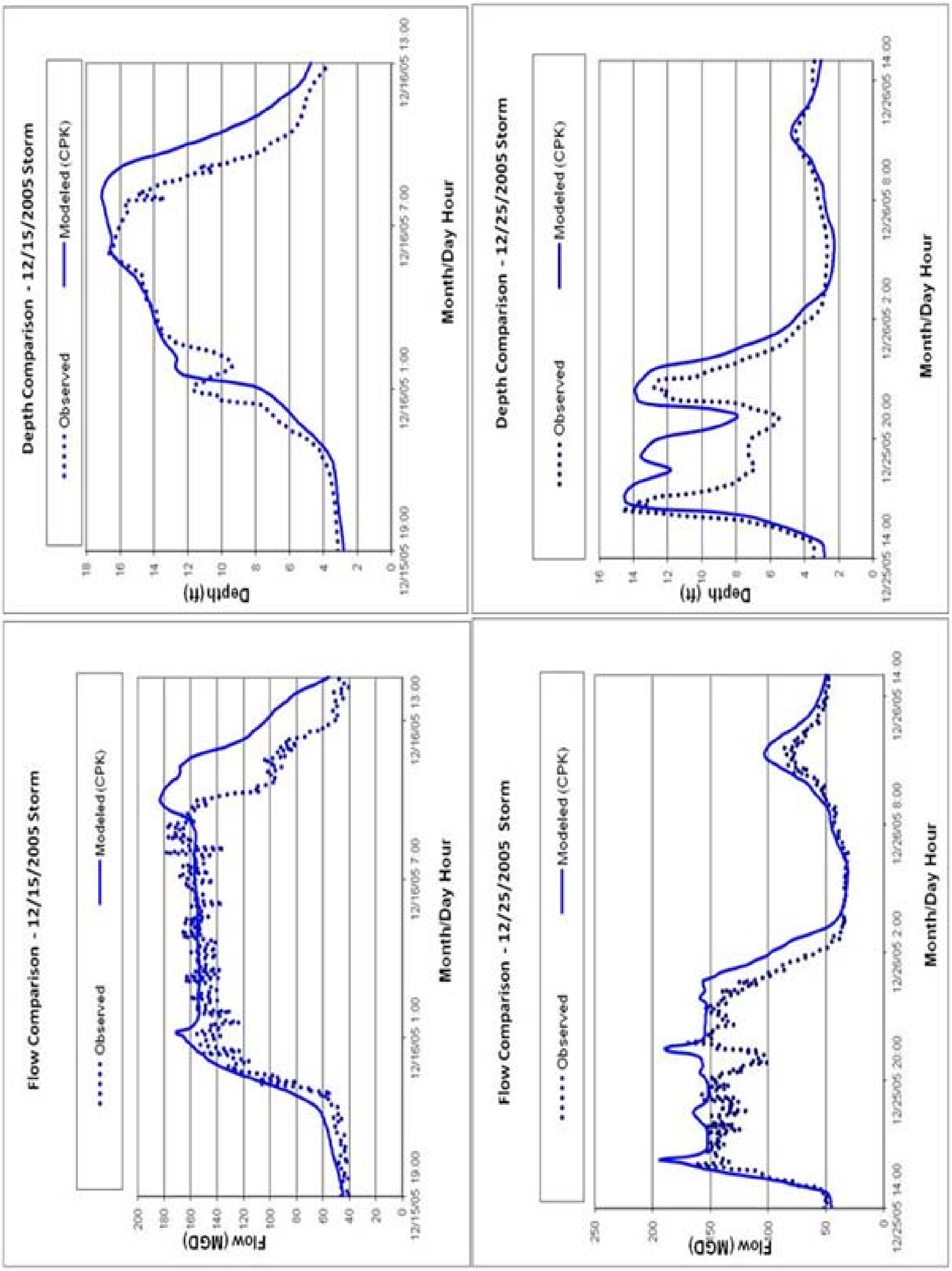
An example of the area-wide recalibration results for an in-system flow monitoring location (M6) is provided in Figure 4-3. This location is within the NC Brooklyn WWTP Kent Avenue interceptor which conveys flow to the WWTP from the East River side of the drainage area. Figures 4-4a and 4-4b provide the resulting goodness-of-fit comparisons for model results and observed flow monitoring data. Overall, the goodness-of-fit for the NC – Brooklyn flow and volume comparisons indicated good agreement between modeled and observed data, and thus no additional changes to the global parameters were employed in the model. As such, the impervious area runoff coefficient of 0.7 provided a reasonably good simulation of the observed flow data for the upstream flow monitoring locations in NC Brooklyn drainage area.



Area-Wide Recalibration Results for an In-System Flow Monitoring Location (M6)

NYCDEP Citywide InfoWorks Recalibration Report

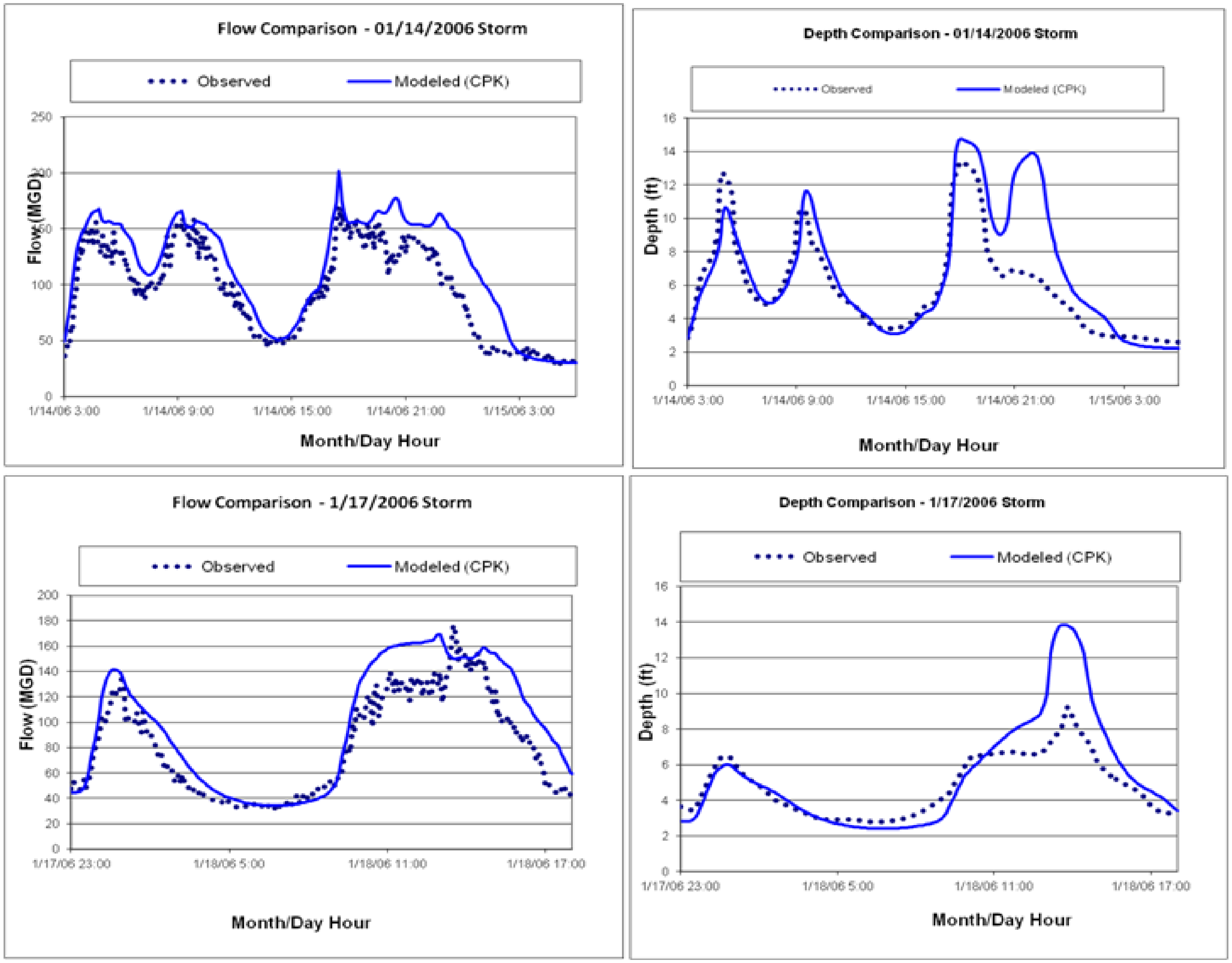
FIGURE 4-3



Goodness of Fit Comparisons 2005 in Brooklyn – East River Side

FIGURE 4-4a

NYCDEP Citywide InfoWorks Recalibration Report



Goodness of Fit Comparisons 2006 in Brooklyn – East River Side

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 4-4b

As noted within the individual sections of Appendix B that contain the detailed results, this area-wide recalibration analysis did result in some changes to global parameters, such as the impervious area runoff coefficients. Some other model parameters and coefficients were also modified, for example, there were cases where adjustments to the average sediment depths in the interceptors were needed to accurately match the observed interceptor depth of flow as well as the flow rate. All of these changes are documented in Appendix B.

However, it should be noted that changes were not considered final at this point in the calibration process as additional efforts were performed to assess the amount of wet weather flow reaching the WWTPs for treatment. These additional analyses are described in the following section.

4.4. WWTP Wet Weather Flow Calibration/Validation

In addition to the use of monitoring data gathered in the collection systems, a continuous simulation for calendar year 2011 was performed for each WWTP drainage area to further calibrate the models based on flow measured at the WWTPs and refine model input parameters as needed.

Hourly precipitation records for calendar year 2011 at the four NOAA rain gages were used, based on their proximity, for each of the WWTP drainage area models. During model calibration, when rainfall was believed to be the reason why modeled hydrographs appeared to have different responses than the observed data for some events, sensitivity runs were performed using data from an alternative NOAA station. The results from these sensitivity runs are discussed in Appendix B.

Particular attention was paid to the operational conditions that existed at the WWTPs, for which adjustments in the treatment capacity thresholds had been necessary (*e.g.*, throttling conditions, process units out of service, maintenance work that limited pumping capacity, etc.). Specific plant upgrades and construction or maintenance work summarized in Table 2-5 were used to modify the model inputs accordingly.

Two methods of comparing modeled and observed plant flows, as discussed below, were developed and analyzed for each WWTP.

1) Annual hydrographs – Hourly flows reaching the WWTP were plotted on a month-by-month basis with rainfall hyetographs. The model-predicted flow rates were plotted against the monitored plant flows.

   An example of this form of graphic is shown in Figure 4-5 for the North River WWTP for the month of September 2011. The observed hourly plant flows are represented by the "*" symbol and the continuous model-predicted flows are shown by the solid line. Hourly Central Park (CPK) rainfall is shown as the black vertical bars. The two horizontal lines on the top of each panel mark the WWC and 2XDDWF flow rates for the WWTP plotted.

2) Probability plots – Frequency of occurrence plots that show the percent of time that flow rates were less than or equal to specified values during the year 2011 were used to examine the ability of IW

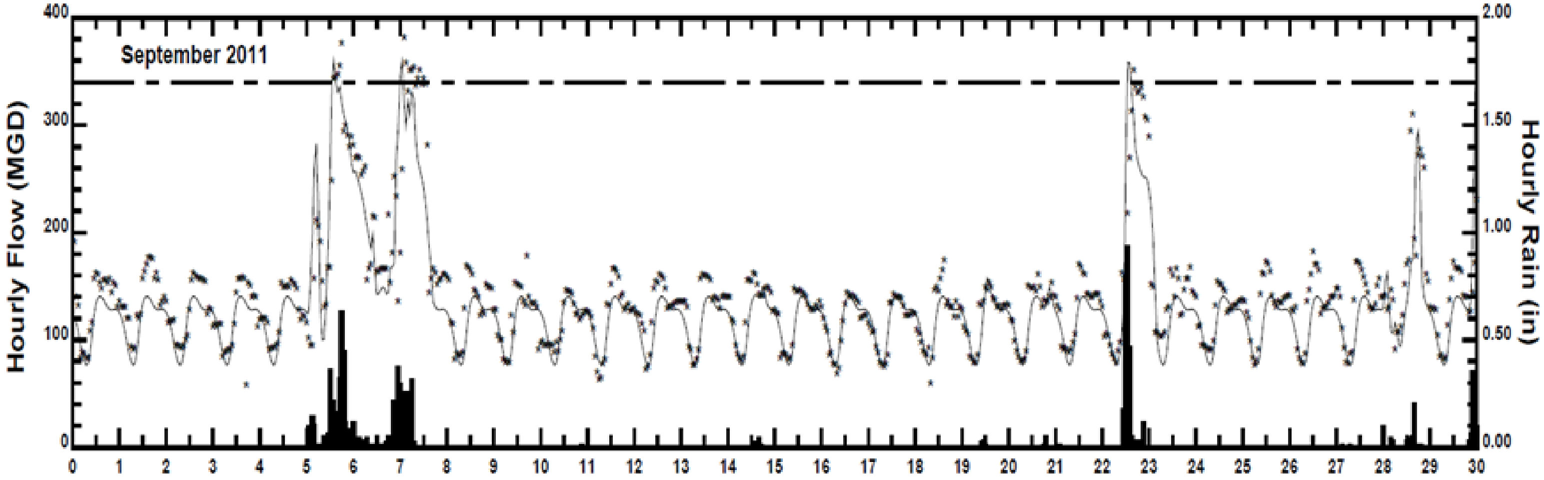
models to simulate WWTP inflow. Two such probability plots were created; the first included all flow data during the year and the second with only wet weather flows. The determination of a wet weather period was based on the 3-hour moving hourly average of rainfall being greater than 0.0 in. Figures 4-6a and Figure 4-6b are the probability plots for all flows and wet hours, respectively.

In each of these graphics the observed hourly plant flow is shown as the open circle "o", while the hourly model-predicted flow is shown as the closed circle "●". Also shown on each of these graphics, as a dashed horizontal line, is the WWTP WWC. In the case of the graphics shown herein for NR WWTP, the rated WWC is at 340 MGD (2xDDWF) for the majority of 2011. It should be noted that to properly simulate the amount of flow reaching the WWTP in excess of the 2xDDWF value, the IW model maximum pumping capacity was set for this 2011 simulation at 360 MGD (2.12xDDWF).

It should be noted also, that these two graphics look different in that the first graphic includes the dry weather periods while the second graphic provides only the information for the periods that are defined herein as wet hours. In this first graphic, the model-predicted flows and observed flows differ somewhat at flows below the 10th percentile. No attempts were made to bring the models into agreement with the data for this portion of the operations as those hours represent dry weather periods.

Calibration results and detailed analysis for each WWTP can be found in the figures in Appendix B. To understand the number of hours that the plants operated at various flow rates during 2011, and to compare that number with the hours predicted by the models , a pair of hourly statistical comparison plots were generated. Example plots are shown in Figure 4-7a and Figure 4-7b. Figure 4-7a shows the cumulative number of observed and modeled hours above the specified flow rate and Figure 4-7b shows the hours between intermediate flow intervals as noted. For plants where the WWC was lower than 2XDDWF, multiples of the WWC are used in the two plots to define the flow thresholds. For the ones with WWC the same as 2XDDWF, multiples of DDWF are used. In these figures, the blue bar represents the number of hours within the year 2011 that the model predicted the flow to occur while the red bar represents the number of hours that flow was observed to occur. Both graphics provide the same information but in a slightly different format. The first of the graphics allows for an examination of the hours that are calculated to exceed the given threshold flows. The second graphic separates the hours into intervals allowing for insight as to flow ranges where the model better represent the observations.

Results for the year 2011 simulation for all IW models are provided in Appendix B along with any adjustments that were made to the models based on this calibration effort using observed WWTP influent flows.

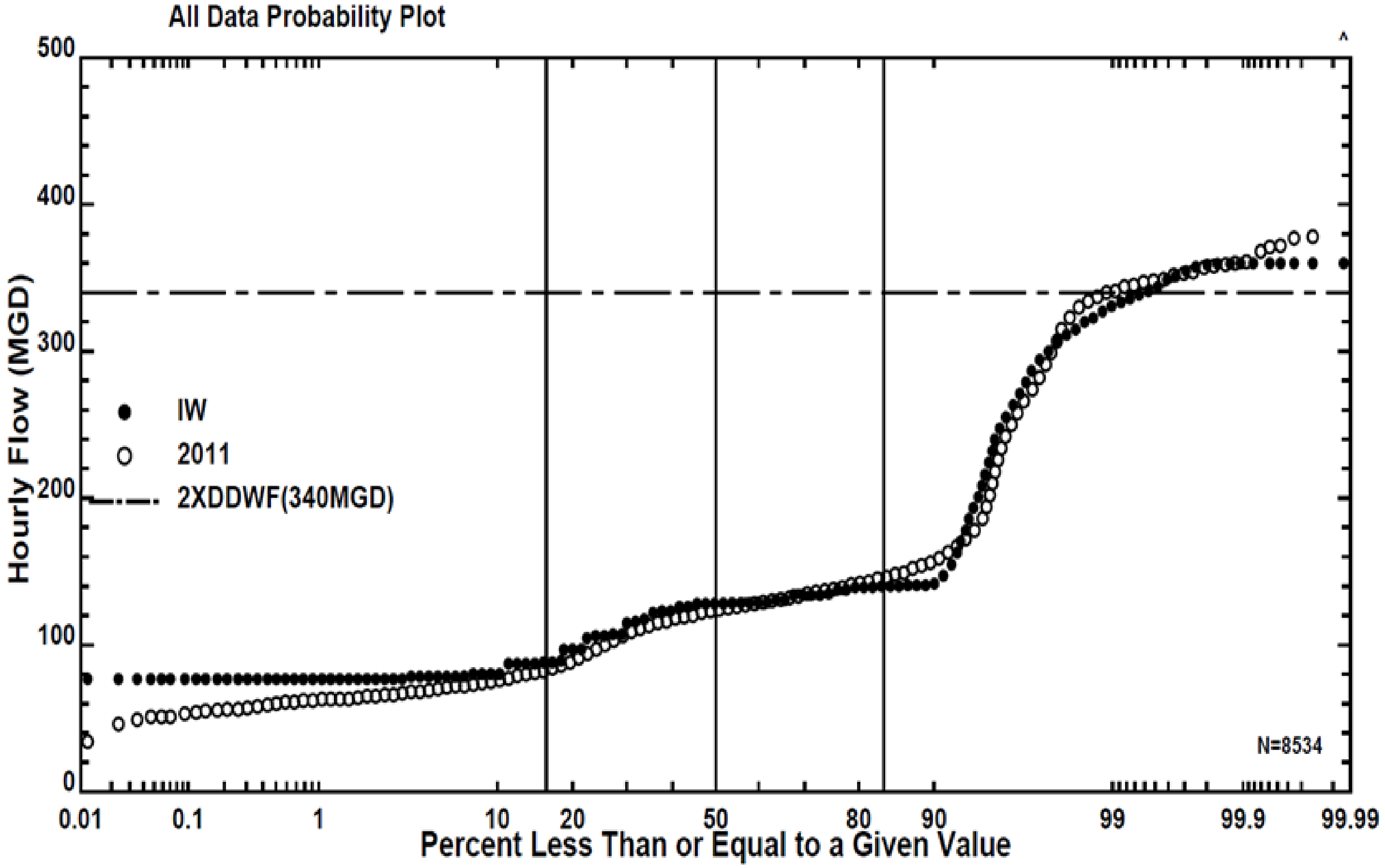


Rain: CPK 2XDDWF= 340 MGD

Monthly Hydrograph of North River

NYCDEP Citywide InfoWorks Recalibration Report

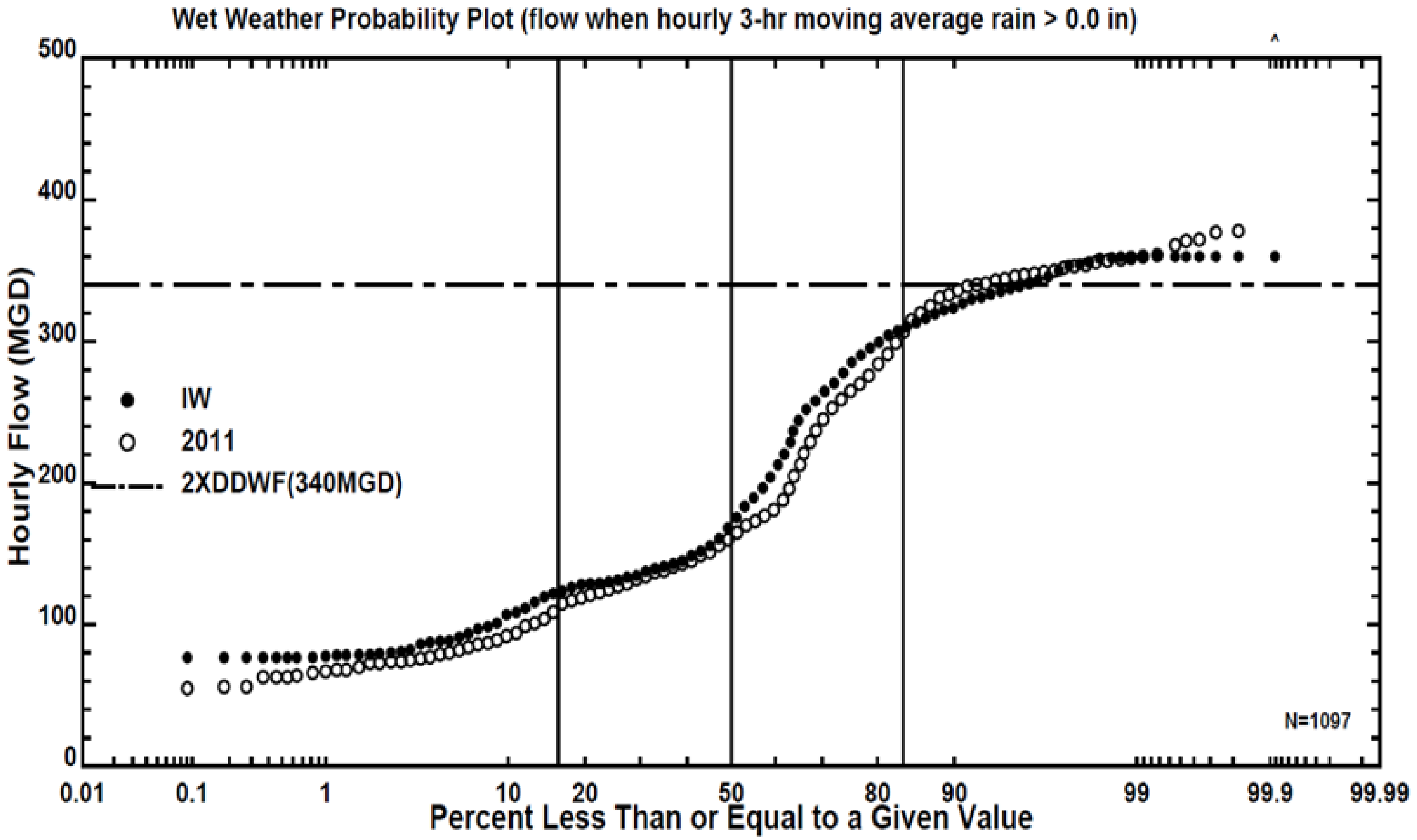
FIGURE 4-5



North River Probability Plot for All Flows

NYCDEP Citywide InfoWorks Recalibration Report

FIGURE 4-6a

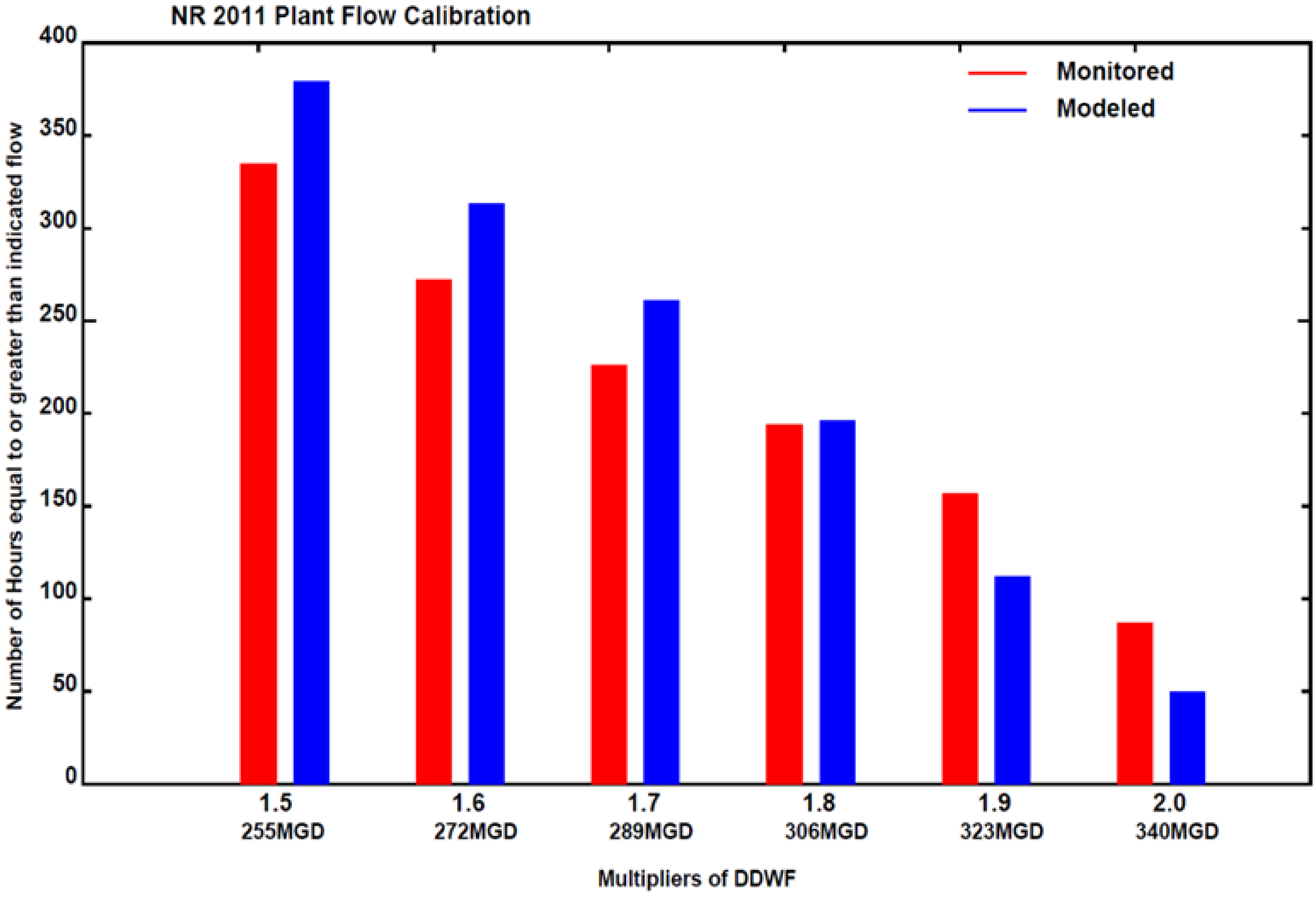


Wet Weather Probability Plot (flow when hourly 3-hr moving average rain > 0.0 in)

North River Probability Plot for Wet Weather Flow

FIGURE 4-6b

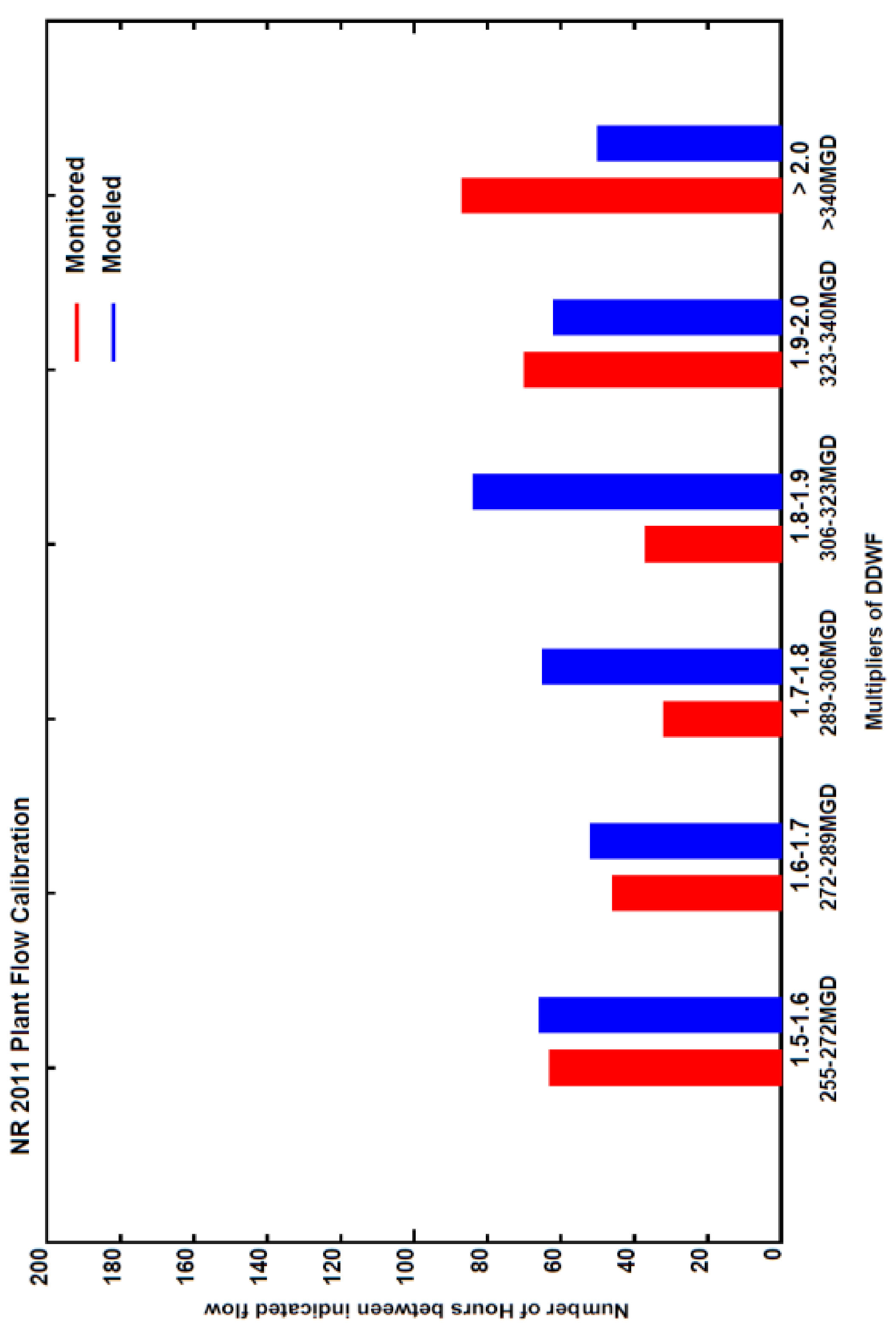
NYCDEP Citywide InfoWorks Recalibration Report



Hours Above the Specified Flow Rate

FIGURE 4-7a

NYCDEP Citywide InfoWorks Recalibration Report



Hours Between Intermediate Flow Intervals

FIGURE 4-7b

NYCDEP Citywide InfoWorks Recalibration Report

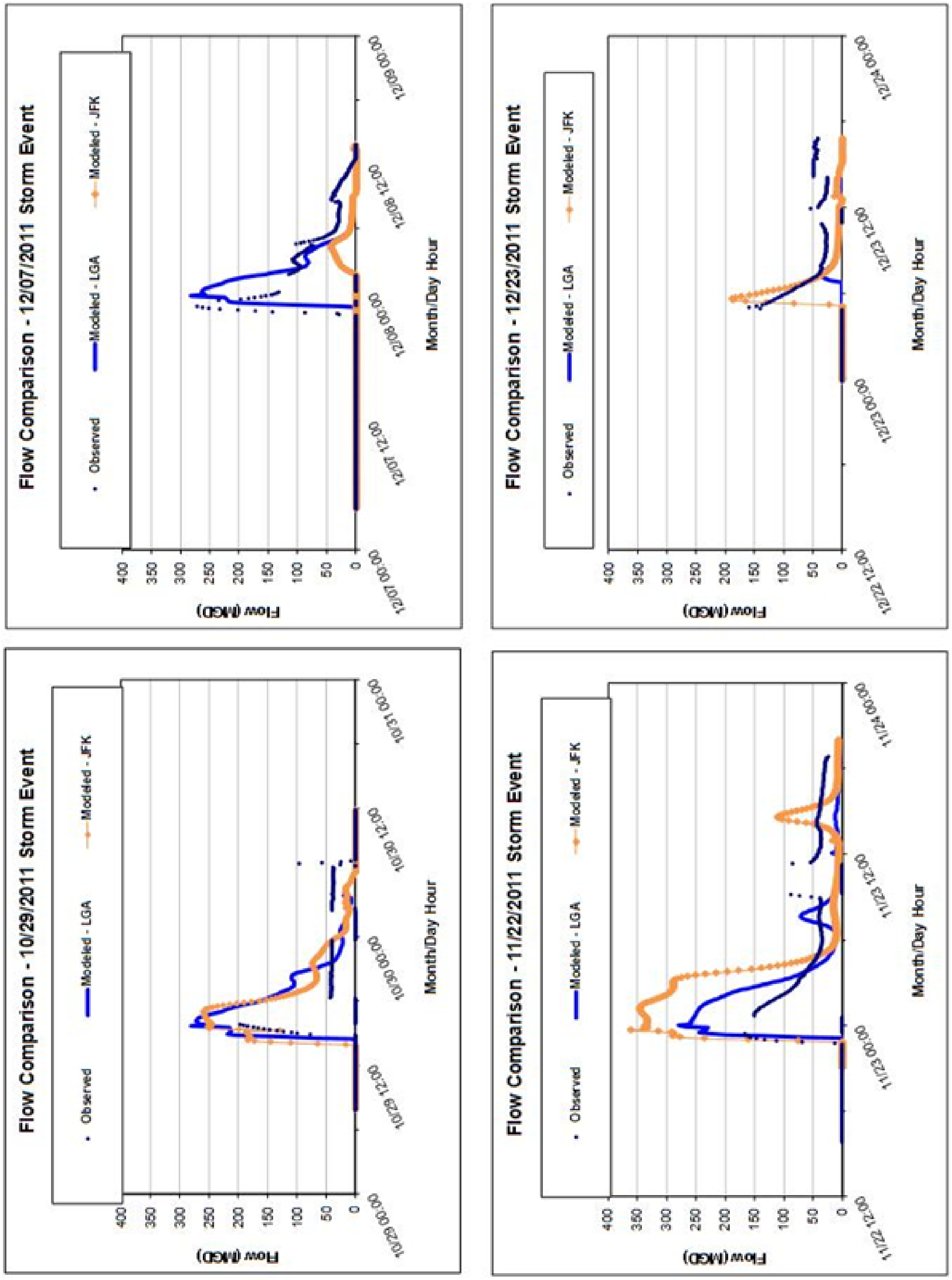
4.5. CSO Retention Facility Calibrations

An additional step taken in the IW recalibration analyses was to use information developed as part of the CSO retention facility Post Construction Monitoring (PCM) of retention facility overflows. Flows monitored at these facilities provide information that is similar in nature to the inflows to the WWTPs - flow measured at the downstream end of a large drainage area. Such information can provide valuable insights into the hydrology of the areas tributary to those facilities.

Two approaches were developed to assess model performance and revise model coefficients as necessary during this portion of the recalibration process:

Event simulations - One approach was to compare IW model-predicted and observed retention facility overflows and/or predicted and observed water depths within the retention facilities during storm events. Figure 4-8 provides a sample of the model simulations and observed flow measurements during four storm events in 2011 for overflows from the Flushing Creek CSO retention facility. Monitored data are shown as the black dots while model calculations are displayed as the blue line for a simulation that used LGA hourly rainfall data and the tan line for a simulation that used JFK data. As noted, the model results appear to bracket the measured overflows. Additional model/data comparisons and detailed discussions of the simulations are provided in Appendix B.

Monthly Volumes – A second approach was to utilize the PCM data that is reported to the NYC DEC as part of the SPDES required Discharge Monitoring Reports (DMR). This data provided summaries of the volumes of measured overflows from retention facilities for various months in the year 2011. Table 4-3 provides a comparison of the IW calculated monthly overflow volumes and DMR values. The table indicates that there are differences between the model results and the reported data. Overall, the model and data provide reasonable comparisons given the difficulties and inaccuracies being experienced by DEP in monitoring CSO retention facility overflows. Based on the magnitude of the differences shown, additional efforts should be focused on refinements in the calibrations as part of the ongoing annual post construction monitoring and report efforts.



Model Simulations and Observed Flow Measurements During Overflow

FIGURE 4-8

NYCDEP Citywide InfoWorks Recalibration Report

Table 4-3 Comparison of InfoWorks Calculated Monthly Overflow Volumes and Reported DMR Values

	Alley Creek CSO Retention Facility		Flushing Creek CSO Retention Facility		Paerdegat Basin CSO Retention Facility	
Month	**2011 DMR Overflow Volume (MG)**	**IW Model Calculated Overflow Volume (MG)**	**2011 DMR Overflow Volume (MG)**	**IW Model Calculated Overflow Volume (MG)**	**2011 DMR Overflow Volume (MG)**	**IW Model Calculated Overflow Volume (MG)**
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	0	29	-	-	-	-
April	9	16	-	-	-	-
May	10	10	-	-	-	-
June	0	15	2	83	0	0
July	5	6	7	36	0	3
August	134	147	-	-	767	763
September	35	47	-	-	254	0
October	0	11	56	63	0	18
November	21	8	22	48	112	46
December	17	14	71	75	176	0
TOTAL	**231**	**304**	**157**	**305**	**1309**	**830**

For the purposes of model recalibration, two changes were made to the impervious runoff coefficient "C" to bring the volumes into the alignment shown in the table. The impervious area runoff coefficients for areas upstream of the Alley Creek CSO retention facility were slightly reduced and the runoff coefficients for areas upstream of the Flushing Creek CSO retention facility were slightly increased.

4.6. Summary of the Area-wide Model Calibration Parameters

As discussed in Appendix B for individual WWTP drainage areas, the hydrology parameters were refined on an area-wide basis during calibration. Any initial adjustments were made as part of the area-wide model recalibrations with the event-based in-system flow monitoring data. Additional adjustments were made to refine the ability of the models to simulate the inflows to each WWTP. Final adjustments were made based on the comparisons between the IW model calculations and the reported CSO retention facility overflows. Impervious surface runoff coefficients were adjusted slightly from the globalized coefficients. The final hydrology parameters are summarized in Table 4-4. Additional model inputs that were changed during this process are provided in the area-wide summaries in Appendix B.

Impervious area runoff coefficients (DCIA to total impervious area ratios) were combined with the land uses for all combined sewer drainage areas within the 13 WWTP drainage areas to calculate the weighted average DCIA, as summarized in Table 4-5. Also summarized in that table is the weighted average impervious area (CSO Imp Area) documented in the October 2007 reports. As noted in Table 4-5, the combined sewer area impervious area totaled about 58,499 acres in the previous 2007 IW models.

The equivalent measure for the new models, DCIA, is about 53,312 acres. This is a decrease of about 8.8 % in the combined sewered impervious area that contributes runoff to the combined sewer system.

Changes are generally small between the CSO impervious areas from the 2007 versions of the model, shown in the third column (CSO Imp Area) and the recalibrated version of the model shown in the last column (DCIA). In general, the differences in impervious cover are +/- 10 percent with the exception of the Bowery Bay high level interceptor drainage area where there is about a 30% decrease in hydraulically connected impervious area. Further insight to these differences is shown in the sensitivity analysis is shown in Section 4.7 of this report.

Table 4-4. Summary of Hydrology Parameter Values for All WWTP Drainage Areas

Surface Type		Impervious		Pervious	
		SFR <=0.25	SFR >0.25	Non Open	Open
Site-scale Runoff Coefficient	Generalized	0.7	0.5	0.4	0.1
Areawide Runoff Coefficient	26	0.5	0.5	0.3	0.1
	BB	0.6 for BBH, 0.7 for BBL	0.5	0.4	0.1
	CI	0.6	0.5	0.4	0.1
	HP	0.7	0.5	0.4	0.1
	JA	0.5	0.5	0.3	0.1
	NC	0.85 for NCM, 0.7 for NCB	0.5	0.4	0.1
	NR	0.8	0.5	0.4	0.1
	OH	0.6	0.5	0.4	0.1
	PR	0.7	0.5	0.4	0.1
	RH	0.55	0.5	0.4	0.1
	RO	0.7	0.5	0.4	0.1
	TI	0.5 for Alley Creek drainge area, 0.6 for the rest of the TI drainage area	0.4 for Alley Creek drainge area, 0.5 for the rest of the TI drainage area	0.3	0.1
	WI	0.7	0.5	0.4	0.1
Site-scale Initial Loss for 75% impervious area with DP(inch)	Generalized	0.02	0.02	0.2	0.2
Site-scale Surface Roughness	Generalized	0.01	0.01	0.05	0.15

Table 4-5 – Summary of October 2007 Impervious Area and Recalibrated IW Model DCIA

WWTP		Old model			New Model (CU data)													
					SFR <=0.25					SFR > 0.25					Total			
		CSO Area (acre)	imp%	CSO Imp Area (acre)	CSO Area (acre)	imp%	Cimp	Cimp X imp%	DCIA (acre)	CSO Area (acre)	imp%	Cimp	Cimp X imp%	DCIA (acre)	CSO Area (acre)	imp%	Cimp X imp%	DCIA (acre)
26		4472	49.6%	2217	4345	87.1%	0.5	0.44	1893	127	77.2%	0.5	0.39	49	4472	86.8%	0.43	1942
BB	**BBH**	8583	73.8%	6334	6635	87.3%	0.6	0.52	3475	2050	80.4%	0.5	0.40	824	8685	85.7%	0.50	4300
	BBL	3574	78.9%	2820	3761	90.3%	0.7	0.63	2377	0	0	0	0	0	3761	90.3%	0.63	2377
CI		7090	59.0%	4181	5363	82.9%	0.7	0.58	3113	1726	83.3%	0.5	0.42	719	7090	83.0%	0.54	3832
HP		11738	56.3%	6613	10815	81.3%	0.7	0.57	6158	923	74.7%	0.5	0.37	345	11739	80.8%	0.55	6503
JA		5645	43.5%	2454	3004	81.7%	0.5	0.41	1227	2641	77.1%	0.5	0.39	1018	5645	79.6%	0.40	2246
NC	**NCM**	3856	73.0%	2815	3908	95.2%	0.85	0.81	3162	0	0.0%	0	0.00	0	3908	95.2%	0.81	3162
	NCB	9596	50.0%	4798	9591	83.0%	0.7	0.58	5572	100	87.5%	0.5	0.44	44	9691	83.0%	0.58	5616
NR		5466	68.0%	3717	5466	87.0%	0.8	0.70	3804	0	0.0%	0.5	0.00	0	5466	87.0%	0.70	3804
OH		8729	63.8%	5573	8370	86.3%	0.6	0.52	4334	359	77.3%	0.5	0.39	139	8729	85.9%	0.51	4473
PR		3576	34.0%	1216	1591	56.0%	0.7	0.39	624	1985	46.0%	0.5	0.23	457	3576	50.4%	0.30	1080
RH		2991	59.0%	1765	2991	90.2%	0.7	0.63	1889	7.8	81.3%	0.5	0.41	3	2999	90.2%	0.63	1892
RO		5709	36.0%	2055	4081	60.0%	0.7	0.42	1714	1628	51.0%	0.5	0.26	415	5709	57.4%	0.37	2129
TI	**Alley Creek Drainage Area**	1735	39.1%	678	826	67.9%	0.5	0.34	280	516	57.3%	0.4	0.23	118	1342	63.8%	0.30	398
	Other Drainage	9740	40.0%	3896	4529	65.8%	0.6	0.39	1788	5309	67.0%	0.5	0.33	1778	9838	66.4%	0.36	3566
WI		12853	57.3%	7369	9907	85.5%	0.7	0.60	5930	417	50.2%	0.5	0.25	105	10324	84.1%	0.58	6035

Notes:

CSO Area - CSO Area refers to combined drainage areas (including seperated storm area and other areas that contribute to combined system) where CU data and DCIA method are applied in the new model. In old model, it refers to the equivalent areas to the new model

imp% - area-weighted percent imperviousness

Cimp - Runoff coefficient for impervious areas

Cimp x imp% - product of imp% and Cimp

4.7. Model Sensitivity Analysis

Model simulations were performed to provide insight on how various changes made to model parameters impact the results. One of the key input parameters is the rainfall that exhibits significant spatio-temporal variations in the NYC landscape. As shown in several calibration/validation comparisons in earlier sections, the differences between radar rainfall data (derived essentially from point gage data) and point gage, or the use of different point gage data, can be significant for each WWTP drainage area. Due to the use of a combination of radar data and multiple point gages, the variability in rainfall is captured reasonably well in the calibration/validation process. Therefore, additional analyses have been performed and described in the following sections to assess: (a) how the overall changes made to the models as part of this effort impact calculated CSO overflows between the 2007 and 2012 IW models, and (b) how changes in the DCIA drainage areas due to the uncertainty in radar imagery data can potentially impact calculated CSO overflows.

4.7.1. Model Updates Since 2007

For the sensitivity analysis, a model simulation was performed using the October 2007 model input files and then compared to a model simulation performed using the revised and recalibrated models. The analysis was performed using the 2011 rainfall hyetograph and the 2011 dry weather sanitary sewage flows for both simulations. For the simulations the rainfall hyetographs were based on the airport rain gauges adjacent to or considered as most representative for each sewershed. All other components of the models (impervious cover, sediment, tides, etc.), for consistency in comparative evaluations, reflected the conditions included in 2007 IW models or reflected all of the updates made as part of this recalibration effort.

The results were then compiled by summarizing the total annual CSO overflow volumes calculated in each simulation for each of the WWTP areas. The results are provided in Table 4.6.

Table 4-6 Calculated 2011 Annual Combined Sewer Overflow Volume

WWTP Drainage Area	October 2007 IW Model Results	June 2012 IW Model Results	Difference	
			(MG/yr)	(%)
Bowery Bay				
Bowery Bay High Level Interceptor	6,806	4,895	1,911	28%
Bowery Bay Low Level Interceptor	2,218	2,156	62	3%
Total	9,024	7,051	1,973	22%
Coney Island	2,140	2,251	-111	-5%
Jamaica	2,646	3,190	-544	-21%
Hunts Point	5,912	5,634	278	5%
Newtown Creek				
Newtown Creek Brooklyn Interceptor	4,031	4,993	-962	-24%
Newtown Creek Manhattan Interceptor	1,371	1,667	-296	-22%
Total	5,402	6,660	-1,258	-23%
North River	1,789	1,497	292	16%
Owls Head	3,004	2,681	323	11%
Port Richmond	1,527	1,545	-18	-1%
Red Hook	1,369	1,364	5	0%
Rockaway	197	237	-40	-20%
Tallman Island	3,266	3,478	-212	-6%
26th Ward	1,892	1,062	830	44%
Wards Island	7,067	6,046	1,021	14%
CitywideTotals	**45,235**	**42,696**	**2,539**	**6%**

As noted in this table, changes in model inputs have resulted in a wide range of impacts on total annual WWTP drainage area CSO overflow volumes ranging from a decrease of 44% for the 26th Ward drainage area to an increase of 23% for the Newtown Creek drainage area. As noted herein, there were many changes made to the models including interceptor sediments, impervious cover, tides, etc.

Examples of changes include:

- For the Jamaica WWTP model, the June 2012 model has significantly more sediment in the interceptor, which is likely the explanation for the calculated 21% increase in annual CSO overflow for the 2011 conditions.

- There were refinements made to the Spring Creek tank that is likely responsible for the 44% decrease in CSO overflows from the 26th Ward WWTP area. An update made to the Autumn Avenue regulator (SPDES Outfall 26-003) also contributes to the 44% decrease.
- New information included in the Newtown Creek interceptors for sediment levels contributes to the calculated 20% increase in annual CSOs using the recalibrated model.

It should be noted that the overflow volumes calculated in Table 4-6 are from year 2011 which experienced rainfall that was nearly 50% higher than normal. Even given this large increase in rainfall above the typical year's rainfall, the changes made to the model in this recalibration exercise represented only a net decrease of 6%.