Prepared for

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FRESH KILLS PARK:
STORM WATER MANAGEMENT PLAN
PART I: MEETING NEW YORK STATE CRITERIA

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ATTACHMENTS

EXECUTIVE SUMMARY

The following report summarizes the stormwater quantity and stormwater quality modeling effort completed for the Storm Water Management (SWM) Plan for Fresh Kills Park. This report is divided into two Parts. Part I describes the proposed project scope and how New York State (NYS) stormwater criteria will be met. Part II (under a separate cover) describes additional goals and project objectives (not required by NYS) for stormwater quality and volume control and how these goals will be met.

The objective of the proposed project is to complement and enhance the aesthetic and ecological purpose of the proposed Fresh Kills Park, while also meeting the overall stormwater management objective to improve upon current hydrologic and water quality management provided by the existing stormwater management infrastructure. As a whole, this Plan evaluates the existing and proposed conditions stormwater infrastructure within the proposed North Park, East Park, South Park, West Park, and Confluence areas located within the existing Fresh Kills Landfill in Staten Island, Richmond County, New York, New York. For the purposes of the SWM Plan, the 5 park areas were divided into 4 watersheds: North Park, East Park, South Park and West Park. The Confluence was divided into the 4 watershed as follows: (1) Creeks Landing is located in North Park; (2) the Terrace is located in South Park; (3) the Marsh is located in East Park; and (4) the Point is located in West Park. Stormwater modeling was completed in EPA SWMM for each park watershed under the following scenarios:

- Existing conditions;
- Proposed Conditions: 2016 build-out with a 2-lane road;
- Proposed Conditions: 2016 build-out with a 4-lane road; and
- Proposed Conditions: 2036 build-out with a 4-lane road.

For Part I of the SWM Plan, Geosyntec developed one existing conditions model and three proposed conditions models (one for each of the proposed scenarios), for each of the four park watersheds. The focus of Part I of the SWM Plan was to design and model proposed conditions stormwater infrastructure for the proposed park system to meet the New York State stormwater management criteria. The proposed features added to the parks to accomplish this were limited to swales, for stormwater conveyance, and stormwater ponds, for peak control. The purpose of Part I of the SWM Plan was to develop proposed stormwater designs for each Park and model these proposed designs under different proposed scenarios to estimate the stormwater quantity and quality improvements achieved compared to existing conditions.

The first phase of the Project included subcatchment delineation, data collection, model development, execution, calibration, and analysis. Subcatchments were delineated using topography and the stormwater management features (i.e. swales, culverts, and downchutes) based on existing reports and drawings. Existing conditions and proposed conditions models were developed for each Park area using EPA-SWMM software, composed of subcatchments, conduits, junctions, and storage units to mimic the existing and proposed stormwater management system. The models were executed and the results were compared against existing monitoring data (for West Park only). For calibration of the model, adjustments were made in the input parameters to match the field measurements more accurately.

The results of the analysis for Part I of the SWM Plan indicate that all NYS stormwater quality and stormwater quantity requirements were met and in many cases exceeded for all proposed conditions for each Park watershed. All outlet structures for stormwater management basins were designed, at a minimum, to provide extended detention for the 1-year, 24-hour design storm, as required for water quality management. For all areas discharging to non-tidal waters, a decrease in the post-development 10-year and 100-year, 24-hour storm event peak discharges was achieved, as required. Additionally, multiple areas discharging to tidal waters also met these criteria, which is not required by NYS but provides additional peak control and water quality benefits above and beyond those required by NYS. Also, for all stormwater management basins, the 100-year, 24-hour design storm event was safely conveyed with a minimum of one-foot of freeboard provided in each basin.

A pollutant loading analysis was also completed for each park. The results of the loading analysis indicate that in general, the total annual loading of total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP) will decrease following build-out, due to the overall decrease in impervious area on-site. Additionally, with the modifications to the existing stormwater ponds, the ponds provide additional load reduction for a total annual load reduction of 67,626 lb/year for TSS, 676 lb/year for TN and 296 lb/year for TP as compared to existing conditions for the park system overall.

The overall goal of the Project is to improve upon existing conditions of the site and to complement and enhance the aesthetic and ecological purpose of the Project. In order to achieve this goal, stormwater management at the site must go above and beyond the requirements of the NYS stormwater criteria alone. The focus of Part II of the SWM Plan is to develop and model proposed conditions of the park system to meet additional stormwater criteria and project objectives, not required under NYS regulations. In Part II of the SWM Plan the stormwater plan and the models developed in Part I of the report were modified to add LID concepts and Stormwater Best Management Practices or BMPs specific to each Park and estimate the stormwater quantity and stormwater quality improvements achieved compared to existing conditions and compared to the results of the Part I analysis.

For Part II of the Storm Water Management (SWM) Plan, Geosyntec modified the three proposed conditions models (one for each of the proposed scenarios), for each of the four Park watersheds, developed in Part I, to incorporate Low Impact Development (LID) techniques. Individual BMPs were added to the proposed site plans in locations outlined in Part I of the plan. The models were modified to include these practices and the models were rerun.

The results of the analysis for Part II of the SWM Plan indicate *(THE PART II ANALYSIS IS CURRENTLY IN PROGRESS)*

A site monitoring plan was submitted to Field Operations (FO) on October 17, 2007 which outlined the installation schedule, monitoring equipment, monitoring locations and the proposed installation of the equipment at the Project site. North Park and East Park were proposed to be equipped first, with installation of monitoring equipment installed on the other Parks as a separate task. Based on rain events and weather patterns, data will be collected from the monitoring equipment periodically, for use in calibration of the models developed as a part of this report. The calibrated models will then be used to better estimate the stormwater quality and quantity results for use during the construction phase of the project.

1. INTRODUCTION

1.1 Terms of Reference

This report was prepared by Geosyntec Consultants, Inc. (Geosyntec) on behalf of Field Operations (FO) for the Fresh Kills Park, Storm Water Management (SWM) Plan.

The purpose of this report is to present the design and modeling results of the Storm Water Management (SWM) Plan for the Fresh Kills Park Project (hereinafter referred to as the Project). The proposed SWM Plan will be designed to complement and enhance the aesthetic and ecological purpose of the proposed Fresh Kills Park, while also meeting the overall stormwater management objective to improve upon current hydrologic and water quality management provided by the existing stormwater management infrastructure.

This report is divided into two Parts. Part I describes the proposed project scope and how New York State (NYS) stormwater criteria will be met. Part II (under a separate cover) describes additional goals and project objectives (not required by NYS) for stormwater quality and volume control and how these goals will be met.

For Part I of the Storm Water Management (SWM) Plan, Geosyntec developed one existing conditions model and three proposed conditions models (one for each of the proposed scenarios), for each of the four Park watersheds. The focus of Part I of the SWM Plan was to design and model proposed conditions of the park system to meet the New York State stormwater management criteria. The proposed features added to the parks to accomplish this were limited to swales for stormwater conveyance and stormwater ponds for peak control. The purpose of Part I of the SWM Plan was to develop proposed stormwater designs for each Park and model these proposed designs under different proposed scenarios to estimate the water quantity and quality improvements achieved compared to existing conditions. Geosyntec produced advanced conceptual-level design details for each selected stormwater control feature.

Specifically, Part I of the report presents: assumptions, methodologies, calculations and procedures used in developing the Project models; the data collection and model calibration procedures; the model simulations conducted for the Project; and the results of the models for existing conditions and proposed conditions under the 2016 build-out (2-lane road); 2016 build-out (4-lane road); and 2036 build-out (4-lane road) scenarios.

This report presents the outcome of the surface water modeling effort at Fresh Kills Park (FKLP or the Park). This Project specifically evaluates the existing and proposed stormwater infrastructure within the proposed North Park, East Park, South Park, West Park, and Confluence located within the existing Fresh Kills Landfill in Staten Island, in Richmond County, New York, New York. For the purposes of the SWM Plan, the 5 park areas were divided into 4 watersheds (North Park, East Park, South Park and West Park). The Confluence was divided into the 4 watershed as follows: (1) Creeks Landing is located in North Park; (2) the Terrace is located in South Park; (3) the Marsh is located in East Park; and (4) the Point is located in West

Park. Outflow from the Park currently discharges into fresh waters and tidal waters. The purpose of the Project was to model existing conditions, and evaluate the proposed stormwater management system to ensure that it meets the New York State Department of Conservation (NY DEC) stormwater management rules and regulations associated with stormwater runoff from redeveloped sites.

For Part II of the Storm Water Management (SWM) Plan (under a separate cover), Geosyntec modified the three proposed conditions models (one for each of the proposed scenarios), for each of the four Park watersheds, developed in Part I of the SWM Plan, to incorporate Low Impact Development (LID) techniques. Individual Stormwater Best Management Practices or BMPs were added to the proposed site plans in locations outlined in Part I of the plan. The models were modified to include these practices and were rerun.

The purpose of Part II of the SWM Plan was to modify the plans and models developed in Part I of the report to add LID concepts and BMPs specific to each Park and estimate the stormwater quantity and stormwater quality improvements achieved compared to existing conditions and compared to the results of the Part I analysis. *(PART II IS CURRENTLY IN PROGRESS)*

1.2 Report Organization

Part I is organized into 8 sections, with accompanying tables, figures, and attachments:

- Section 2 provides project background information.
- Section 3 discusses the methodology utilized to develop the models, including a discussion of the New York requirements, the model goals, and a discussion of each model included in the project.
- Section 4 discusses the hydrologic and hydraulic assumptions and calculations performed.
- Section 5 discusses the calibration of the hydrologic model and presents the modeling results.
- Section 6 describes the methodology utilized to develop the water quality model for the project, including a discussion of model inputs, results, and discussion.
- Section 7 describes conclusions from the modeling effort for both water quantity and water quality standpoints.
- Section 8 provides document references.

1.3 Limitations

The overall objective of this project was to develop models for the existing and proposed stormwater infrastructure under three scenarios (described previously). In developing the models, Geosyntec worked closely with FO staff in understanding existing conditions (As-Built, Final Cover Conditions) at the landfill in order to model the existing landfill condition more accurately. Geosyntec relied on visual reconnaissance and FO provided CAD and report information in understanding existing site conditions.

Proposed conditions CAD information (i.e. construction drawing sets, as-build drawing sets, drainage system details, cross-sections, etc.) for each park was also provided by FO. Proposed stormwater management infrastructure was designed by Geosyntec based on proposed conditions provided by FO.

2. PROJECT BACKGROUND

Fresh Kills Landfill is located in Richmond County on the western portion of Staten Island, New York, New York. The site is bisected by the West Shore Expressway (Route 440) and Fresh Kills, Main, and Richmond Creeks. The site is bounded to the north by Victory Boulevard and Travis Road, Richmond Avenue to the East, Arthur Kill Road to the South, and the Arthur Kill Waterway to the West (see Attachment 1 - Site Locus).

The approximately 2200 acre site is divided into four park watersheds: (1) North Park; (2) South Park; (3) East Park; and (4) West Park. Primary access to the existing site is via the Muldoon Avenue exit off of the West Shore Expressway. An established network of site roads provides access to each of the site areas. Landfill gas and leachate collection systems are located throughout the site. Most of the Department of Sanitation offices are located in the central portion of the site.

By the late 1990s, landfilling operations ceased on all mounds (parks) at Fresh Kills Landfill and final closure activities began. Following the events of 9/11/2001, West Park was used for disposal of the World Trade Center debris. As of 2007, disposal operations at all mounds have ceased and final closure activities are either underway or complete. The site is currently managed by the New York Department of Sanitation. Plans to redevelop the landfill area into a multi-use park are currently underway. The proposed multi-use park area will include athletic fields, numerous paths, visitor and education centers, and additional roads.

2.1 Project Goals

The main goals for the Storm Water Management (SWM) Plan for the Fresh Kills Park Project are as follows. The part of the SWM Plan that addresses each of the project goals is shown in parenthesis:

1. Characterize stormwater runoff discharge rates and volumes for each park area under existing conditions (Part I).
2. Characterize stormwater runoff discharge rate and volumes for each park area under the proposed redevelopment scenarios (Part I).
3. Characterize stormwater runoff discharge rate and volumes for each park area under proposed redevelopment scenarios incorporating LID (Part II).
4. Estimate the annual per acre pollutant loads for Total Suspended Solids (TSS), Total Phosphorous (TP), and Total Nitrogen (TN) for each park area under existing conditions (Part I).
5. Estimate the annual per acre pollutant loads for TSS, TP, and TN for each park area under the proposed redevelopment scenarios (Part I).
6. Estimate the annual and per acre pollutant loads for TSS, TP, and TN for each park area under the proposed redevelopment scenarios incorporating LID (Part II).

7. Develop design parameters for various stormwater management best management practices (BMPs) recommended within predetermined subareas (Part I).
8. Show the benefit and/or impact of employing various BMP techniques and treatment systems (Part II).
9. Based on an approved park master plan, develop a proposed site SWM Plan for each proposed park area (North Park, South Park, East Park, and West Park) (Part II).

In the implementation of the above stated project goals a strong effort was made to:

- improve overall Park aesthetics;
- improve the ecological benefits of Park areas;
- maximize new wetland features; and
- protect and enhance existing wetland features.

2.2 Modeling Basis

The Fresh Kills Landfill site is located on Staten Island, in Richmond County, New York, New York. The New York State Department of Conservation (NY DEC) is charged with the responsibility of enforcing state stormwater management rules and regulations. Stormwater runoff from new construction sites is regulated under the New York State Storm Water Management Design Manual (NYDEC, 2003). The Storm Water Management Design Manual criteria apply to land development sites disturbing more than one acre of land. The criteria can be grouped into two categories: (1) water quantity management; and (2) water quality management. The modeling basis was to conform to all requirements of the New York State Department of Conservation rules and regulations.

2.3 Park Areas

The Fresh Kills Park is divided into four parks – North Park, South Park, East Park, and West Park. Each park area consists of a landfill mound, landfill mound perimeter, and adjacent areas. The four landfill mounds that are located within the North, South, East, and West Parks are identified as Mound 3/4, Mound 2/8, Mound 6/7, and Mound 1/9, respectively. Each of these mounds and perimeter areas is to be converted to four active and/or passive recreation areas, collectively known as Fresh Kills Park.

2.4 Health and Safety Plan

The activities undertaken for this Project included both office and field activities. A Health and Safety Plan (HASP) has been prepared for the field activities. This plan describes health and safety procedures that were followed during the implementation of the Project, and will be followed during implementation of future phases. The HASP is provided in Attachment 2.

3. ASSESSMENT METHODOLOGY

3.1 Modeling Methodologies

The Fresh Kills Park Project stormwater management system was represented in a hydrologic model to re-create the existing and estimate the proposed drainage conditions on-site, for three different proposed project scenarios. The hydrologic model chosen was the EPA Storm Water Management Model (SWMM), version 5.0. SWMM is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps (USEPA, 2005). Input parameters related to each runoff and routing component of the model are described in Section 4 of this report.

SWMM has been continuously refined since its inception in the late 1960s/early 1970s and the current working version is number 5.0, which is a complete re-write of the previous release. Running under Windows, SWMM 5 provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses (USEPA, 2005). Both the EPA SWMM version 4.0 and version 5.0 manuals will be referenced in this document. SWMM version 5.0 is more software based, while SWMM 4.0 includes software instructions as well as theory behind each function. The hydrologic and hydraulic theory is consistent between both versions.

3.2 New York State DEC SWM Requirements

3.2.1 Redevelopment Requirements

According to NY DEC, redevelopment refers to “reconstruction or modification to any existing, previously developed land such as residential, commercial, industrial, institutional or road/highway which involves soil disturbance” (NYDEC, 2004). The New York State DEC has recognized that although site constraints can hinder implementation of stormwater management water quality controls, redevelopment sites provide opportunities for improving stormwater runoff water by providing some level of treatment that may not exist under current conditions.

The redevelopment criteria can be summarized as follows:

1. Deviations from standard approved Stormwater Quantity Controls may be accepted under the following conditions:
    a. the redevelopment results in no increase of impervious area or changes to hydrology that increases the discharge rate; and
    b. existing Quantity Management Controls must be maintained in post-development flow discharge control.
2. All standard Stormwater Quantity Controls apply under the following conditions:
    a. if the redevelopment results in an increase of the total impervious area and subsequently increased discharge rate; or
    b. if the redevelopment results in modified hydrology or flow due to discharge to other subwatersheds, slope change, direct channelization, curb-line modification, etc.
3. Deviations from standard approved Stormwater Quality Practices can occur under the following conditions:
    a. if the proposed plan reduces the total site impervious cover by 20 percent; or
    b. if a minimum of 25 percent of the water quality volume (WQ_v) from the disturbed area is captured and treated by standard stormwater management practices.
    c. If a combination of standard and non-standard practices are proposed and the non-standard practices treat 100 percent of the WQ_v from the practices contributing area.
4. All standard Stormwater Quality Practices apply for areas of new development if the project includes a combination of new development and redevelopment.

The design and modeling efforts for the redevelopment of the Fresh Kills Landfill into the Fresh Kills Park will be based on addressing the above redevelopment criteria for stormwater management. The proposed design for Fresh Kills Park Project will not increase site imperviousness at final build-out (2036). See Table 3.1, below, for existing and proposed impervious area percentages for each park in the Project.

Existing impervious surfaces at the Project site include roads, parking lots, paved material storage areas, buildings, and other areas with a paved or otherwise impervious surface (e.g, landfill gas flare stations). Proposed impervious cover includes proposed roads, primary paths, proposed and remaining existing structures, and other areas with a paved or otherwise impervious surface (e.g, landfill gas flare stations). Secondary paths, including bike trials and walking trails, were not considered impervious for proposed conditions, since they are not proposed to be paved but, instead, will have a pervious gravel or slag surface. Additionally, all existing roads will be completely removed and will remain only if the location of the proposed road overlaps the existing road. Where existing roads overlap proposed locations of secondary paths, the road will either be removed or crushed in place to create a pervious surface. This results in a net decrease in impervious cover of 27% for the proposed build-out (2036 4-lane) condition.

Table 3.1 Estimated Existing and Proposed Project Imperviousness

Park Area	Total Park Area (Acres)	Existing Acreage of Impervious Surface[1]	Proposed Acreage of Impervious Surface[2,3]		
			2016 (2-lane)	2016 (4-lane)	2036 (4-lane)
North Park	**260**	23	16	18	18
East Park	**435**	31	43	48	35
South Park	**211**	20	14	15	9
West Park	**664**	108	120	124	69
TOTAL	**1571**	**182**	**193**	**205**	**132**

1 Existing impervious cover delineated from 1-foot orthophoto (Image date: 12/06 and 03/07)
2 Non-road impervious cover provided in the Fresh Kills Park Master Plan (ARKF, 2006)
3 Impervious cover from roads delineated from proposed road locations (ARUP, 2007)

Due to the layout of proposed roadways on the Project site, existing site quantity management controls (on-site detention basins) may not be able to be maintained in some locations. They may be filled in some areas and expanded in others. The existing on-site detention basins are assumed to have been designed to meet bare soil final closure conditions, so it is assumed that the basins are oversized for final closure vegetated conditions or existing conditions (see Attachment 3 – Verified Existing Final Closures Stormwater Management Plan submitted to the client in July 2007 by Geosyntec). However, since modifications to sizing and existing outlet control structures are proposed, the Project does not meet Redevelopment Criteria 1.

Components of the project include proposed buildings, paths, recreation areas, etc., which will modify existing site surface cover and grading. These changes will inevitably modify site hydrology, including direction of stormwater flow. Therefore, in accordance with Redevelopment Criteria 2, all standard stormwater quantity controls apply to the Project.

The proposed plan reduces the total site impervious cover by 27% at 2036 build-out. However, road construction and remaining existing roads and structures on West and East Parks slated to remain in 2016 actually results in a slight increase in the total impervious cover for the 2016 scenarios. State redevelopment regulations require a 20% reduction of total site impervious area. However, since standard stormwater management practices are proposed to be modified to treat the WQ_v, Redevelopment Criteria 3 will be met, and deviations from the traditional stormwater quality practices are permissible. Additionally, since the Project is entirely redevelopment and no new development will be taking place, Redevelopment Criteria 4 does not apply.

In summary, the proposed Project does not meet the requirements for redevelopment for stormwater *quantity* control and, therefore, must meet all standard NYS stormwater quantity controls. The proposed Project will meet the requirements for deviation from standard approved stormwater *quality* practices once all stormwater management practices have been sized and outlet structure modified to capture and treat a minimum of 25% of the WQ_v as required under

Redevelopment Criteria 3. Standard approved stormwater quality practices are proposed for the site in combination with other more innovative technologies, not specifically included in the New York State Storm Water Management Design Manual. Since Redevelopment Criteria 3 is met, LID technologies are permissible on site. Part II of this report will discuss the design and modeling of all LID components of the Project.

3.2.2 Stormwater Quantity Management

For most land development sites disturbing over one acre of land, the New York State Storm Water Management Design Manual requires the following:

- Channel Protection: Provide 24-hour extended detention for the 1-year, 24-hour storm event;
- Overbank Flood Protection: Control the post-development peak discharge rate from the 10-year, 24-hour storm to pre-development rates;
- Extreme Storm Protection: Control the post-development peak discharge rate from the 100-year, 24-hour storm to pre-development rates; and
- Safely convey 100-year storm event stormwater flows with 1-foot of freeboard.

The New York State Stormwater Management Design Manual also states that for stormwater management outfalls discharging to tidal waters, no management is required for stream channel protection, overbank protection, or extreme storm protection. According to 33 CFR Part 328 Section 328.3, "the term **"tidal waters"** means those waters that rise and fall in a predictable and measurable rhythm or cycle due to the gravitational pulls of the moon and sun. Tidal waters end where the rise and fall of the water surface can no longer be practically measured in a predictable rhythm due to masking by hydrologic, wind, or other effects."

Under existing conditions, stormwater runoff from the Fresh Kills Park generally discharge to tidal waters, either through surface runoff from the park side slopes or through a pipe after being collected into a stormwater pond. However, stormwater runoff from a number of Park ares discharge through freshwater wetlands or forested areas before discharging to tidal waters (these discharges are referred to as "non-tidal waters").

Since, in most cases, the ultimate outfalls for each park are not expected to change from the existing to proposed conditions, no management is required for stream channel protection, overbank protection, or extreme storm protection for the areas on the Park that currently discharge into tidal waters. Stormwater controls installed on the areas that do not directly discharge to tidal waters must abide by all state regulations indicated above. The drawing set included in Attachment 5 identifies which basins and park areas discharge to tidal waters versus non-tidal waters. These maps show that approximately 63% of the total site discharges to tidal waters for the existing condition. The remaining area must be treated according to NYS requirements.

All stormwater management proposed for the Fresh Kills Park must also meet requirements stated in Part 360 of state regulations for solid waste management facilities which indicate that the "drainage control structures must be designed, graded, and maintained to prevent ponding and erosion to the cover. The surface drainage system must be designed and constructed to protect the cover from, at a minimum, the peak discharge of a 24-hour, 25-year frequency storm" (Part 360, Subpart 2, Section 15 (k)).

3.2.3 Stormwater Quality Management

The New York State Storm Water Management Design Manual requires water quality management be provided to capture and treat 90 percent of the average annual runoff volume discharging from a developed site. Stormwater management practices must be selected from a pre-approved practice list and sized for control of the water quality volume (WQ_v). In accordance with the NYS Design Manual, stormwater ponds sized to hold the water quality volume have an average pollutant removal efficiency of 80% for total suspended solids, 50% for total phosphorous, and 35% for total nitrogen.

The Water Quality Volume (WQ_v) is designed to improve water quality sizing to capture and treat 90% of the average annual stormwater runoff volume. The WQ_v is directly related to the amount of impervious cover created at a site. The following equation can be used to determine the water quality storage volume WQ_v (in acre-feet of storage):

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

where:

WQ_v = water quality volume (in acre-feet)
P = 90% Rainfall Event Number
R_v = 0.05 + 0.009(I), where I is percent impervious cover
A = site area in acres

A minimum R_v of 0.2 is required, regardless of percent impervious cover. It is assumed that by meeting the WQ_v requirements through employment of the standard approved stormwater management practices a project will, by default, meet water quality objectives (NYS DEC, 2001).

3.3 Project Models

To evaluate the hydrologic and water quality benefits of the proposed SWM Plan, Geosyntec developed an existing condition site hydrology and water quality model for each Park area. This existing conditions model provides a baseline condition that was used as a reference for selection of potential stormwater management system features and production of useful conceptual-level designs. It also served as a baseline for design, sizing, and evaluation of a SWM system to service the completed multi-use site. Once the existing models were in place, proposed models for 3 different conditions were developed:

- 2016 (2-lane road): This condition demonstrates proposed park features that would be installed in the year 2016. Under this condition, no proposed features are constructed on East Park or West Park. All roads are complete within the park system, with the exception of the Richmond Hill Road Extension. All main features in North Park and South Park, including the eastern half of Creeks Landing (a portion of The Confluence that is located in the North Park watershed) and The Terrace (located in the South Park watershed) are constructed by 2016. The western half of Creek Landing, however, is not. Other portions of The Confluence located within the East Park and West Park watersheds – namely the Marsh (located in East Park) and The Point (located in West Park) – are not constructed in this scenario.
- 2016 (4-lane road): This condition is the same condition as above, except instead of a 2-lane road, a 4-lane road is modeled and therefore the percent imperviousness of each park is increased.
- 2036 (4-lane road): This condition demonstrates the proposed Master Plan with all proposed features constructed for all Parks. In this case the roadway is a 4-lane road.

3.3.1 Existing Conditions

Design plans as well as hydrologic and hydraulic (H&H) modeling and design computation reports were collected and reviewed to characterize the existing infrastructure for each park under final closure conditions (existing conditions). This information was used to set up the initial baseline existing conditions hydrologic and hydraulic model. Attachment 4 includes a table which describes the data and plan sets that have been compiled for this effort as of December 2007.

Additional information on existing infrastructure including verification of locations and design features of existing storm drain infrastructure, length and cover characteristics of various flow paths, and identification of locations of erosive conditions or locations where ponding of stormwater is occurring, etc. was collected during a field visit in May 2007 and was added to the stormwater infrastructure site condition assessments already completed by Shaw Environmental and Infrastructure Engineering for the City of New York Department of Sanitation (Shaw, 2004). Updated existing conditions site drawings are provided in Attachment 5.

From the previous assessment reports and additional field reconnaissance, Geosyntec analyzed land cover characteristics, location, and design of existing drainage channels and other conveyance features, road alignments, road material, detention basin capacity, outlet design, and flow routing. Spot elevations along the existing embankments, water surface elevations, basin bottom elevations, and invert elevations of drainage infrastructure in key stormwater management ponds were surveyed and data included in the models.

A number of stormwater infrastructure features currently exist within these Park areas. Table 3.2 provides a brief summary of the existing stormwater management and stormwater conveyance features located at each landfill mound, based on plan data sets provided to Geosyntec.

Table 3.2 Existing Stormwater Management Infrastructure

Park	Swales	Downchutes	Other	SWM Basins	Park Area in Acres[1]	Approximate Managed Acres[2]
East Park	54	6	7 Drop Inlet Boxes	6	434.5	300.4
North Park	28	16	*	4	260.2	124.2
South Park	20	13	14 Drop Inlet Boxes	3	211.4	125.7
West Park	47	2	7 Drop Inlet Boxes	7	664.5	578.4

[1] The area calculated for each Park area includes the landfill mound and perimeter areas up to the tidal wetland.
[2] Managed areas are areas that are treated with a Stormwater Pond prior to discharging off-site.
[3] Attachment 4 includes a list of documents used to compiling all existing conditions data on Fresh Kills Landfill.

Along with conveyance systems and ponds typical of engineered landfill stormwater management systems, there exist a number of culverts designed to convey stormwater runoff under access roads. Existing storm drain outfalls discharge to tidal waters of Main Creek, Richmond Creek, Fresh Kills Creek, and Arthur Kill. Outfall channel protection in the form of riprap channels, typical of landfill stormwater conveyance systems, exists at many of the mound stormwater basins.

In addition, there are offsite drainage systems from adjacent roads and communities that discharge to some of the park stormwater basins and perimeter areas. The North Park area, for example, receives stormwater runoff from the community of Travis. The hydrology modeling effort does not include these offsite areas, since these areas will not be disturbed as a part of this project.

3.3.2 Proposed Conditions

The overall scope of the construction activities for the proposed project consists of grading and re-planting of the site for the construction of a multi-use park area. Soil will be added to existing surfaces as needed to obtain desired grades. Specifically, a minimum soil layer of 2-feet in depth will be added over the entire extent of North Park and South Park, due to the unsuitable soil fill used in these areas of the landfill cap. Additional roads and paths will be constructed according to the details to be outlined in the final design plans. Park areas will be vegetated based on the details to be specified in the final design plans. Although final design plans are not complete, modeling was done using the Master Plan drawings dated 2006 to develop preliminary proposed conditions estimates for each Park. Proposed conditions site maps for all four parks, under proposed conditions 2016 build-out and proposed conditions 2036 build-out are included in Attachment 5.

Under the Fresh Kills Park Master Plan, most of the Fresh Kills Landfill site will be converted to public open space and parkland. The SWM Plan was designed to complement and enhance the aesthetic and ecological purpose of the proposed park areas, while also meeting the overall stormwater management objective to improve upon current hydrologic and water quality management provided by the existing stormwater management infrastructure. Stormwater quantity and quality management was designed to achieve all required NYS stormwater criteria.

Proposed stormwater management for the park system consists of traditional conveyances and storage measures including the existing armored downchutes and swales and large-scale detention ponds with modified outlet control structures. These “traditional” stormwater techniques are currently in place on the landfill and will remain in place, in most cases, or be modified or reconstructed in new locations to manage the proposed conditions. These stormwater conveyance and control methods will continue to be used to achieve NYS stormwater criteria, but will be modified accordingly, to fit into the proposed park design.

Modeling assumptions for 2016 build-out conditions include:

- Existing conditions landfill cover type (i.e., vegetation);
- Existing conditions storm water management features (i.e., conveyances, downchutes, storm water management basins);
- Proposed road is crowned in the middle and either side runs to a drainage swale which runs parallel to the road;
- Proposed road swales drain into existing conveyance (i.e., swale) where feasible, contributing to existing storm water management basins;
- Pervious surfaces were considered to be any area covered with vegetation, soil, gravel, or other surface which allows the infiltration;
- Impervious cover was considered to be any structure, paved area (e.g., roadway, parking area), equipment storage area, or other landfill infrastructure area;
- All currently existing impervious area in the East and West Parks was assumed to remain in 2016 unless in direct conflict with a roadway proposed to be built in 2016; and
- All currently existing impervious areas in the North and South Parks was assumed to have been removed unless otherwise noted in the Master Plan.

Modeling assumptions for 2036 proposed conditions final build-out include:

- Proposed park cover type, based on Fresh Kills Park Master Plan;
- Existing roads to be removed were modeled as pervious surface;
- Existing conditions storm water management features (i.e., conveyances, downchutes and storm water management basins) were utilized;
- Proposed 4-lane road is crowned in the middle and either side runs to a drainage swale which runs parallel to the road;

- Proposed road swales drain into existing conveyance (i.e., swale) where feasible, contributing to existing storm water management basins;

- Pervious surfaces were considered to be any area covered with vegetation, soil, gravel, or other surface which allows the infiltration;

- Impervious cover was considered to be any structure, paved area (e.g., roadway, parking area), equipment storage area, or other landfill infrastructure area; and

- All currently existing impervious areas in all parks were assumed to have been removed unless otherwise noted in the Master Plan.

To achieve advanced stormwater management of the park system, an innovative approach to managing stormwater at the site will be proposed. This approach will utilize a mixture of traditional conveyance and storage measures (including the existing armored downchutes and large-scale detention ponds) and smaller, controls selectively located throughout each subcatchment that are designed to enhance hydrologic and water quality function and the aesthetic and habitat quality of the completed site (e.g., pocket wetlands, vegetated treatment swales, planter boxes). By utilizing upstream stormwater controls, runoff flows will be routed through multiple levels of treatment prior to discharge off the Project site.

A preliminary list of appropriate BMPs for each proposed park feature was developed to help build the overall stormwater management plan for the park. For example, pocket wetlands, grassed or vegetated swales, raingardens, and porous pavement were identified as appropriate stormwater management BMPs modules for application along proposed paved paths and paved roads. The complete list is provided in Table 3.3.

Table 3.3 List of BMPs for Proposed Park Features

BMP	Proposed Park Feature	Proposed Park Feature Key
Bioretention cell	Ppl, AFi, Dj	➢ Pavement (paths) – Pp
Constructed wetland	Do	➢ Pavement (roads) – Pr
Dry well	B	➢ Pavement (parking lot) – Ppl
Grass/Vegetated filter strip	Sg	➢ Slopes (steep) – Ss
Grass swale	Pr, Sg, AFp	➢ Slopes (gradual) – Sg
Green roof	B	➢ Athletic Fields (impervious) – AFi
Infiltration trench	AFi, B, Dj	➢ Athletic Fields (pervious) – Afp
Planter box	Ppl	➢ Buildings – B
Pocket wetland	Pr, Dj	➢ Drainage (junction) – Dj
Porous pavement	Pp, Pr, Ppl, AFi	➢ Drainage (outfall) – Do
Raingarden	Pp, Sg, AFp, B	
Riprap inlet filter ring	Do	
Riprap outlet protection	Dj, Do	
Slope stair stepping	Ss	
Stormwater pond	Do	
Vegetated treatment swale	Pr, AFi, Dj	

The proposed conditions drawings, including general proposed LID Control Areas, for all four parks are included in Attachment 5. These maps show general areas where each type of BMP may be proposed. Individual BMPs are not shown on these drawings. These drawings are preliminary and are to be used only to achieve a general idea of where BMPs may be proposed. A full description of LID management practices and LID modeling including site specific BMP locations for each park will be presented in Part II of the SWM Plan.

Geosyntec produced advanced conceptual-level design details (approximately 60 percent concept design) for each selected stormwater control feature. See Attachment 5 for details of selected BMPs proposed for the Project.

4. STORMWATER QUANTITY: MODEL APPROACH AND INPUTS

The SWMM model analysis in the Part I analysis is tailored to address all New York State DEC criteria for new developments. A model run was completed for the proposed 1-year storm to ensure proper design of the on-site Stormwater Management Practices (SMPs) for channel protection. Model runs were computed for the existing and proposed conditions 10 and 100 year, 24 hour frequency storms to show that the existing condition discharge rate is equal to or greater than the post-development condition discharge rate. In addition, the 100-year water surface elevation (WSE) in all basins under proposed conditions were assessed to ensure the basin designs meet the required freeboard needed for the New York State Department of Environmental Conservation, Division of Water, Guidelines for Design of Dams (NYDES, 1989).

A description of key model inputs and SWMM model components are included in the following sections.

4.1 Precipitation

Rainfall information was gathered from a regional source to accurately represent historical rainfall conditions. Historical rainfall data for the Project vicinity was obtained from the National Climate Data Center at the following station:

(i) Station ID. 6026, Newark International Airport, is located in Essex County approximately 8 miles north of the Project site at latitude 40:40:00, longitude 74:10:00 and at elevation 7 feet MSL. Rainfall records were available for the Newark station for 1948 through 2006 in 60-minute increments (NCDC, 2005).

A statistical frequency analysis was performed using the Statistics tool within the SWMM model for the historical rainfall events within the 59-year Newark gage record. A Statistics Report was generated from the time series of simulation results. For a given object and variable, the statistics report can do the following:

- Segregate the simulation period into a sequence of non-overlapping events, either by day, month, or by flow (or volume) above some minimum threshold value;
- Compute a statistical value that characterizes each event, such as the mean; maximum, or total sum of the variable over the event's time period;
- Compute summary statistics for the entire set of event values (mean, standard deviation and skewness); and
- Perform a frequency analysis on the set of event values (USEPA, 2005).

The statistical frequency analysis was performed to determine the return periods of the historical rainfall events. An inter-event time of 6 hours was entered for the event-dependent time period. The statistics report was generated which organized each gage record into independent rainfall events with a total rainfall that occurred over the duration of the event. A frequency analysis of the independent events was performed which calculated the frequency at which a particular event has occurred and estimated the return period for each event. It should be noted that the return period calculation is dependent on the gage period of record (i.e., 59 years).

The results of the statistical analysis are compared to the results from the Type III, 24-hour, SCS Synthetic Rainfall maps in Table 4.1.

Table 4.1 Return Period Rainfall for Fresh Kills Park

Return Period (years)	X-Year, 24-Hour Rainfall (inches)	
	NRCS Rain Gage	SCS Synthetic Rainfall Map
1-Year	2.7	2.5
2-Year	3.4	3.3
5-Year	4.3	4.5
10-Year	5.4	5.1
15-Year	6.8	-
25-Year	-	6.4
60-Year	8.1	
100-Year	-	7.5

The results show that the rainfall amount for the lower return periods are only slightly different, with the error between the gage and the rainfall maps increasing as the return period increases. This comparison is due to the sample size for the rain gage used. The Newark gage has a shorter period of record, so it assumes that the highest rainfall event in that record is the rainfall amount for the highest return period it can assume, which was the 60-year return period. For modeling purposes, the SCS Synthetic Rainfall Map Return Period rainfall amounts were used.

4.2 Hydrology

4.2.1 Subcatchment Delineation

Existing Conditions:

Each Park watershed was delineated into drainage areas or subcatchments based on topography and locations of existing drainage swales, downchutes, pipes, and culverts recorded in previous design reports and plans reviewed as part of this project. The existing topography provided by FO and dated May 10, 2007 was used to delineate subcatchments under the existing conditions.

Drainage area maps for existing conditions to each stormwater management infrastructure feature were developed by overlaying the latest one-foot aerial topography with the digital infrastructure layer. Drainage area delineations for existing conditions can be found on the existing conditions site maps located in Attachment 5.

Proposed Conditions:

A proposed condition plan was developed by Geosyntec based on the proposed Park Master Plan dated 2006. Based on this plan and the proposed locations of paths, recreational fields, roadway, etc. and the layout of the existing and proposed swales, the subcatchment delineation for the proposed conditions was determined.

Drainage area maps for proposed conditions were developed using a proposed grading data layer and site feature layer, developed by Geosyntec, and are found on the proposed conditions site maps located in Attachment 5.

4.2.2 Subcatchment Characterization

EPA SWMM 5.0 software requires four physical parameters for each subcatchment:

(i) **Area -** The area of each subcatchment was calculated from the delineations shown in Attachment 5;

(ii) **Width -** According to the SWMM 4.0 Manual, the width of the watershed is the physical width of overland flow. In ideal watersheds, this width is approximately twice the length of the main drainage channel. In more realistic, irregular watersheds, the width can be approximated by dividing the area of the subcatchment by the maximum length of overland flow. For the models presented in this report, this more realistic approach was utilized, in which the maximum length of overland flow was approximated based on site topography;

(iii) **Slope -** The subcatchment slope should reflect the average along the pathway of overland flow to the inlet location (USEPA, 2005). The slope for each subcatchment was approximated based on flow path and topography; and

(iv) **Percent impervious area** - Impervious area calculations for the existing conditions of each subcatchment were estimated by visual inspection of the aerial photographs. Impervious area calculations for the proposed conditions were taken from the 2006 Master Plan and data for proposed roads provided by FO.

4.2.3 Evapotranspiration

Under natural conditions, a fraction of surface water and moisture in the upper soil (vadose) zone may circulate back to the atmosphere via evapotranspiration processes (Thornwaite, 1948). It is assumed that vegetative uptake (and subsequent loss via transpiration) is significant within the existing on-site detention basins and will be significant in the proposed BMPs. Estimation of relevant modeling parameters (wilting point, pan evaporation rates) will be "best guess," although there may be some data from related examples to serve as a basis. A more simplistic method of simulating evapotranspiration is to model the process in EXTRAN using pipes or pumps that divert flows out of the system.

Lacking regional empirically-based estimates, a handful of generalized models of varying complexity are available with which to simulate these processes. The Thornwaite model (Thornwaite, 1948), used for this analysis, is a relatively simple empirical model that calculates a monthly ET rate as a function of temperature.

$$ETP_i = 1.6 \cdot \left[10 \cdot \frac{T_i}{I}\right]^a$$

where: ETP = evapotranspiration rate (cm/month) for month i

T_i = mean monthly temperature (deg C) for month I (derived from NOAA estimates)

I = heat index, calculated as:

$$I = \sum_{1}^{12} \left[\frac{T_i}{5}\right]^{1.514}$$

$a = 6.75x10^{-7}(I^3) - 7.71x10^{-5}(I^2) + 1.79x10^{-2}(I) + 0.49$

The Thornwaite model yields total ET volume for each month of the year, which may be input directly into SWMM. Water removed via ET in the model is subtracted from the available water balance. In SWMM, evaporation can occur for standing water on subcatchment surfaces, for subsurface water in groundwater aquifers, and for water held in storage units. Table 4.2 presents estimated monthly evapotranspiration rates for Staten Island, New York, New York.

Table 4.2 Monthly Evapotranspiration Rates for Staten Island

Month	Temperature (°C)	Evapotranspiration Rate (in/month)
Jan	0.33	0.04
Feb	1.56	0.18
Mar	5.72	0.63
Apr	11.22	1.19
May	16.89	1.76
Jun	21.94	2.25
Jul	25.06	2.56
Aug	24.39	2.49
Sep	20.33	2.10
Oct	14.28	1.50
Nov	8.67	0.93
Dec	3.28	0.00

4.2.4 Watershed Infiltration

Infiltration was estimated for the Park area using the Green-Ampt infiltration equation. EPA SWMM 5.0 performs these calculations with three input parameters: (i) average capillary suction at the wetting front (SUCT), (ii) initial moisture deficit (IMD), and (iii) saturated hydraulic conductivity of the soil (K_s). The soils in the Park were assumed to be C soils (sandy clay loam), based on previous design reports (each Park is composed of compacted fill used to cap the landfill). The soil type was then used to correlate the input parameters for the model as follows:

- The SUCT, IMD and K_s values for the soil type were determined from the SWMM Manual Soil Characteristics Table and were chosen based on the soil type used, sandy clay loam.

Under proposed conditions, the soil type and Green-Ampt infiltration parameters remained the same for the East and West parks. However, the proposed conditions for the North and South Park include adding 2-feet of soil above existing grade. This soil is assumed to have a higher infiltration capacity than the existing soils. A loam soil under hydraulic soil group B has been assumed to be the fill type for these two Parks. Thus, the Green-Ampt infiltration parameters from the SWMM manual changed to those corresponding to a loam.

Additional information used in the infiltration computations for each subcatchment included the Manning's roughness coefficient (i.e. "n") values and the depression storage for impervious and pervious soils. Manning's n values for impervious coverage, pervious coverage, and bare soil were used for existing conditions, depending on the conditions of the subcatchment based on the latest aerial photography and field verification. Manning's n values for impervious coverage and pervious coverage for proposed conditions were based on the cover type specified in the Master Plan. All Manning's n values for each cover type were obtained from the SWMM 5 Manual. Depression storage values for impervious surfaces and pervious surfaces for existing and proposed conditions were obtained from the SWMM 5 Manual, based on cover type of the existing and proposed conditions of each park. The default value for the percent of impervious area without depression storage (25%) was used for all subcatchments.

4.3 Hydraulics

In addition to hydrologic modeling capabilities, SWMM contains a component for hydraulic modeling, used to route runoff and other inflows through the drainage system network of pipes, channels, storage/treatment units, and diversion structures (SWMM Website). The model translates the runoff generated from each subcatchment into flow directed to a junction in the drainage system network. For this Project, junctions represent nodes on the storm drain system (i.e. drop inlets, curb inlets, or manholes). The junctions are connected by links, or conduits, (i.e. drainage swales or storm drain system pipes). The outlet to the storm drain system for each watershed ultimately flows into a detention basin or stormwater pond, which is modeled as a storage unit.

4.3.1 Junction Characterization

Junctions are drainage system nodes where conduits join together. Physically they can represent the confluence of natural surface water channels or pipe connection fittings (EPA, 2005).

In this Project, junctions were used at several locations with the following purposes:

(i) As the outlets of the subcatchments, to allow for the runoff generated from the subcatchment to be collected and subsequently routed through the storm drain pipe network;

(ii) As connection points for a series of swales; and

(iii) In locations where inlets/manholes/and catch basins exist.

The three principal input parameters for a junction are: (1) invert elevation, (2) maximum depth (i.e., depth from the ground surface to the invert), and (3) ponded surface area when flooded. The data for each of these parameters was determined from the design plans reviewed as part of the project, or from site topography.

4.3.2 Conduit Characterization

Conduits are linear features, such as pipes or channels that convey water from one junction to another in the drainage system network. SWMM uses the Manning equation to express the relationship between flow rate, cross-sectional area, hydraulic radius, and slope in open channels and partially full closed conduits (EPA, 2005). The principal input parameters for a conduit and the information source for this Project are as follows:

(1) **Inlet and Outlet Node Identifiers –** The identifiers of the inlet and outlet nodes for each conduit;

(2) **Cross-sectional Geometry Shape –** The cross-sectional geometry of the conduits is generally trapezoidal or triangular for swales, and circular or elliptical for pipes and culverts;

(3) **Conduit Length –** The length of each conduit in plan view was calculated based on the design reports and plans and site topography;

(4) **Conduit Depth –** The depth of the conduit was entered as the diameter of the conduit or the depth of the swale;

(5) **Manning's Roughness –** The Manning's roughness coefficient used was determined based on the material of the pipe or the cover type in the swale. The pipe material was generally obtained from the design drawings and included the following pipe materials:

- Corrugated Metal Pipe (CMP);
- Concrete Pipe (CP); and
- High Density Polyethylene Pipe (HDPE).

Swale cover type was generally obtained from design drawings and verified with the latest aerial photography and field observations. Swale cover types included:

- Grass cover;
- Vegetated cover; and
- Riprap cover.

(6) **Offset Heights of the Conduit Above the Inlet and Outlet Node Inverts –** The offset height was calculated as the difference between the conduit invert elevation and the junction invert elevation; and

(7) **Entrance, Exit, and Average Pipe Losses –** The entrance, exit, and average pipe losses are the loss coefficients associated with energy losses at the entrance, exit and along the length of the conduit, respectively. Entrance and exit losses for all circular

pipes modeled were determined to be 0.5 and 1.0, respectively, from *Fundamentals of Fluid Mechanics*.

4.3.3 Storage Units Characterization

Storage units are drainage system nodes that provide storage volume. Physically they represent storage facilities as small as a catch basin or as large as a lake. The volumetric properties of a storage unit are described by a function or table of surface area versus height. The storage and discharge mechanisms of each detention pond and were represented in the Hydraulics layer of the EPA-SWMM model as storage units. The principal input parameters for storage units include: (1) invert elevation, (2) maximum depth, (3) initial depth, (4) stage-area relationship, (5) evaporation potential, (6) ponded surface area when flooded, and (7) external inflow data (EPA, 2005).

Values for existing pond invert elevation, maximum depth, and the stage-area relationship were obtained from plans and reports reviewed as part of this project. For wet ponds, initial depth was obtained from survey data done in September of 2007. The value for the ponded surface area when flooded was the top surface area of the storage unit, and no external inflow was modeled for any of the ponds. Pond outlet structures on all Parks were modeled based on As-Built plans from North Park and East Park. It was assumed that all ponds had similar outlet structures. Each pond was modeled as having a 4-inch low flow orifice on the basin bottom and a 3-ft riser pipe approximately 2.5-feet below the elevation of the emergency spillway. The 4-inch outlet was used to approximate the flow from the 12-inch perforated caped outlet pipe, wrapped in geotextile, and covered in stone. Exact elevations for each pond riser pipe were not available. Some outfall risers were modeled as greater than 2.5-feet below the emergency spillway elevation (known) to facilitate flow leaving through the outfall pipe during the 10-year storm event.

All existing ponds were also modeled for the proposed conditions. The pond dimensions and stage-storage curves were modified for Ponds F and Q in North Park and Ponds B1 and C in East Park. This was solely due to the fact that the proposed road alignments required modification of the basin geometry. No other stage storage relationships were modified for existing ponds for the purpose of this report. Three additional ponds were added for the proposed conditions, one along the western perimeter of North Park, one along the northern perimeter of the North Park, and one along the southwestern perimeter of South Park to capture runoff which would otherwise drain off-site without being captured and treated. The outlet structures on all ponds were modified to ensure that each pond met the requirements of the NYS storm water criteria. To meet channel protection volume requirements (24-hour extended detention for the 1-year, 24-hour storm event), all outlet structures for basins were designed to hold the water quality volume for 24-hours before being released. This was accomplished by modifying the outlet structures for all existing basins by raising the low-flow orifice to hold the water quality volume in a wet pond and adding a weir structure to provide extended detention. In most cases the ponds were modeled as wet ponds or wet extended detention ponds as described in the New York Design Manual.

For each existing or proposed stormwater management pond, Geosyntec developed a stage-storage routing table. These tables were used as input into the SWMM model. Stage-storage discharge information for each existing and proposed pond is included in Attachment 6.

4.3.4 Groundwater Flow

The groundwater component of water resources at Fresh Kills Park is not modeled in the SWMM model, nor is it anticipated that groundwater has a significant effect on surface water on the majority of the Park system. Since the Parks will be built on existing landfills, the groundwater table is well below the surface of the Parks, with the exception of the low lying perimeter areas located adjacent to tidal waters. The effect of the groundwater table in these areas is not expected to have an influence on the model.

4.3.5 Dynamic Routing

Flow routing within a conduit link in SWMM is governed by the conservation of mass and momentum equations for gradually varied, unsteady flow. The three routing options are: (i) Steady Flow Routing, (ii) Kinematic Wave Routing, and (iii) Dynamic Wave Routing. For this Project, Dynamic Wave Routing was chosen as the routing methodology. Dynamic Wave Routing solves the complete one-dimensional Saint Venant flow equations and therefore produces the most theoretically accurate results. These equations consist of continuity and momentum in conduits and volume continuity at nodes. With this form of routing, it is also possible to represent pressurized flow (i.e., when a closed conduit becomes full) in which the actual flow in the conduit can exceed the full-flow Manning's equation value. Flooding occurs when the water depth at a node exceeds the maximum available depth. The excess volume/flow then ponds atop the node based on the allowable ponding area until the water depth decreases and the volume/flow re-enters the drainage system network or is lost from the drainage system network if the volume/flow exceeds the allowable ponding area.

In addition to pressurized flow, Dynamic Wave Routing can account for channel storage, backwater effects, entrance/exit losses, and flow reversal. Because it combines the solution for water levels in nodes and flows in conduits, it can be applied to any general network layout (EPA, 2005).

5. MODEL ANALYSIS AND RESULTS

After compiling the hydrologic and hydraulic parameters for the existing and proposed conditions models the data was organized into the EPA-SWMM 5.0 model. Model simulations were then performed to calibrate the data in order to match observed conditions, such that the watershed response could be predicted under potential future rainfall scenarios.

A description of the monitoring data used and a description of the calibration process and model results are presented in the following sections.

5.1 Monitoring

Limited monitoring data, consisting of daily flow totals for a number of basins, was available for the calibration of the existing conditions model. This data was used to roughly calibrate the model, in absence of continuous flow monitoring data. A monitoring plan was submitted to FO on October 17, 2007 (with additional revisions sent in December 2007) describing an installation schedule, monitoring equipment, and monitoring locations for additional data to be collected on-site for the continued calibration of the models.

In order to conduct a preliminary model calibration for existing conditions, Geosyntec utilized the flow monitoring data conducted by Severn Trent, between July 2006 and June 2007. Modeling data was available for basins on East Park (i.e., Basin A, Basin B1, Basin R, Basin C1) and West Park (i.e., Basin K1, Basin L, Basin N). Since “final build” conditions were modeled for East Park, which was under construction at the time of the report, and had not yet been entirely capped, modeling results would not correspond well to existing conditions. Therefore, East Park modeling data was not used for calibration. West Park was also not capped, but was modeled “as is” and was therefore selected to be used for calibration. No calibration was completed for North Park or South Park since no monitoring data was provided for these areas.

Data for Basin L and Basin N were used for calibration for the month of July 2006 and verification for the month of September 2006. The data consisted of total daily flow measurements into the basin. Continuous rainfall data was used to calculate the daily flows for Basin L and Basin N from the SWMM model.

5.2 Calibration

Calibration is the comparison of a model to field measurements, other known estimates of output, or another model known to be accurate, and the subsequent adjustment of the model to best fit those measurements. The West Park watershed was modeled using the characteristics of the subcatchments and stormwater system and the recorded rainfall from the historic rainfall gage located at the Newark Airport.

The model was calibrated using the measured total daily flows from instrumentation installed at the inlet of the culverts leading out of Basin L and Basin N. Tables depicting the actual modeled and calibrated-model daily flows during the period of record are provided in Attachment 7.

The data in Attachment 7 show that the original modeled results for total daily flows out of Basin L and Basin N were much higher and generally occurred earlier than the actual monitored data.

To reduce the time to peak in the watershed, the subcatchment Manning's N-value for pervious surfaces was increased from 0.15 (short grass) to 0.24 (dense grass). Additionally, since the model was estimating much higher flow volumes than the actual data suggests, it is expected that more infiltration is occurring in the watershed then was originally expected. Therefore, the Green-Ampt parameters for infiltration were also modified as a part of the calibration process. Initially, all of the parks were modeled as having sandy clay loam under Hydraulic Soil Group C. Since West Park is still under construction and has not yet been capped, the soils in this Park may have a higher infiltration rate. The infiltration parameters were changed to correspond to loamy soil under Hydraulic Soil Group B and the model was re-run.

The calibrated-model results are still much higher than actual conditions, but did decrease some from the originally modeled results. Other factors that could be modified to improve the accuracy of the model include the diameter and invert elevation of the outlet pipe from each basin. Also, the inlet protection measures installed on outlet culverts may be clogged and could be inhibiting flow through the culverts. However, since monitoring data was not provided for the surface water elevation in the pond or the flows into the pond, which are much better variables for model calibration, no further calibration was conducted. Field monitoring will be conducted on site by Geosyntec, and this data will be used to further calibrate each of the park models at a later date.

No modifications to the North Park, East Park, or South Park model was conducted, since monitoring data was not provided for these areas.

Tables providing input information for the existing conditions and proposed conditions models are provided in Attachment 8.

5.3 <u>Results and Discussion</u>

Each Park model was run using the SCS 10-year and 100-year, 24-hour rainfall events. The results for each park are summarized in the following sections. Attachment 9 includes SWMM status reports and summary results tables for each park for each return period event simulation conducted.

5.3.1 North Park

Tables 5.1 to 5.3 display a summary of the model results for peak discharge for each park outlet for North Park, under the three proposed condition models.

Table 5.1 North Park – Difference in Peak Discharge from Pre to Post: 2016 (2-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin D	20	10.6	-59%	-14.7	15.8	-69%	-34.6
Basin E	19	20.6	-46%	-11.6	32.4	-9%	-3.1
Basin F	18	13.4	-52%	-6.8	18.3	-9%	-2.5
Basin Q	17	16.3	-64%	-14.6	17.4	-52%	-18.5
Northwest (NT)	25	14.4	-6%	-1.0	27.5	-18%	-6.1
Southwest - New Basin Y (NT)	26	12.5	-26%	-4.4	25.9	-15%	-4.5
Northwest - New Basin Z	27	9.0	-63%	-16.7	18.0	-65%	-33.3
South	28	11.7	-53%	-11.3	14.9	-54%	-17.8
East	29	0.0	-100%	-13.9	0.0	-100%	-23.5
West (NT)	30	10.7	-68%	-22.1	19.1	-67%	-38.9

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.2 North Park – Difference in Peak Discharge from Pre to Post: 2016 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin D	20	10.3	-59%	-14.7	15.8	-69%	-34.6
Basin E	19	14.5	-43%	-10.8	32.7	-8%	-2.8
Basin F	18	16.3	24%	3.2	38.2	42%	11.4
Basin Q	17	16.3	-29%	-6.6	35.4	-1%	-0.5
Northwest (NT)	25	16.0	-6%	-1.0	27.5	-18%	-6.1
Southwest - New Basin Y (NT)	26	12.8	-25%	-4.3	26.2	-14%	-4.2
Northwest - New Basin Z	27	9.9	-63%	-16.7	18.0	-65%	-33.3
South	28	8.5	-60%	-12.7	14.0	-57%	-18.7
East	29	0.0	-100%	-13.9	0.0	-100%	-23.5
West (NT)	30	10.5	-68%	-22.1	19.1	-67%	-38.9

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.3 North Park – Difference in Peak Discharge from Pre to Post: 2036 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin D	20	10.3	-59%	-14.7	15.8	-69%	-34.6
Basin E	19	14.5	-43%	-10.8	32.7	-8%	-2.8
Basin F	18	16.3	24%	3.2	38.2	42%	11.4
Basin Q	17	16.3	-29%	-6.6	35.4	-1%	-0.5
Northwest (NT)	25	16.0	-6%	-1.0	27.5	-18%	-6.1
Southwest - New Basin Y (NT)	26	12.8	-25%	-4.3	26.2	-14%	-4.2
Northwest - New Basin Z	27	9.9	-63%	-16.7	18.0	-65%	-33.3
South	28	8.5	-60%	-12.7	14.0	-57%	-18.7
East	29	0.0	-100%	-13.9	0.0	-100%	-23.5
West (NT)	30	10.5	-68%	-22.1	19.1	-67%	-38.9

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

The North Park is expected to be at proposed build-out by 2016, with the exception of the western half of Creeks Landing.

North Park 2016 (2-Lane) (Table 5.1) results comparing pre-development to post-development modeled results indicate that peak discharge decreased for the 10-year and 100-year design storms for all basins.

North Park 2016 (4-Lane) (Table 5.2) results are identical to those of the North Park 2036 (4-land conditions). All of the features in Creeks Landing proposed to be built after 2016 are landscape and not structural features and as such, the 2036 and 2016-4 Lane conditions were modeled the same.

North Park 2036 (4-Lane) (Table 5.3) results comparing pre-development to post-development modeled results indicate that peak discharge decreased for the 10-year and 100-year design storms for all basins except Basin F. Discharge from Basin F increased by 3.2 cfs (24%) during the 10-year event and by 11.4 cfs (42%) during the 100-year event. Basin F discharges to tidal waters and therefore, deviation from the NYS requirements is acceptable. The volume of Basins F and Q is significantly reduced under proposed conditions because of impacts from the proposed roadway. Basin F and Q are heavily impacted by the proposed road. Additional stormwater control measures will be installed upslope of these basins to compensate for the volume reduction required for construction of the roadway.

5.3.1.1 East Park

Tables 5.4 to 5.6 display a summary of the model results for peak discharge for each park outlet for East Park, under the three proposed condition models.

Table 5.4 East Park – Difference in Peak Discharge from Pre to Post: 2016 (2-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin A	3	25.2	7%	1.7	53.1	2%	0.9
Basin B1 (NT)	2	27.1	-1%	-0.3	39.1	-9%	-3.7
Basin B2 (NT)	-	-	-	-	-	-	-
Basin C1	1	45.1	7%	2.8	61.6	5%	2.7
Basin C2 (Spillway Only)	100	0.0	0%	0.0	4.6	-	4.6
Basin R	47	35.8	19%	5.8	54.0	17%	7.9
South Tidal	200	6.7	-7%	-0.5	12.7	-3%	-0.4
Confluence	300	4.9	-21%	-1.3	10.4	-15%	-1.8
North Tidal	400	10.4	66%	4.1	17.7	52%	6.1
Fresh Wetland (South)	500	4.3	1%	0.0	8.8	0%	0.0
Fresh Wetland (North)	600	2.8	7%	-	5.6	5%	0.3

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.5 East Park – Difference in Peak Discharge from Pre to Post: 2016 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin A	3	25.2	7%	1.7	53.1	2%	0.9
Basin B1 (NT)	2	25.4	-8%	-2.1	42.3	-1%	-0.6
Basin B2 (NT)	-	-	-	-	-	-	-
Basin C1	1	45.4	7%	3.1	62.1	6%	3.2
Basin C2 (Spillway Only)	100	0.0	0%	0.0	6.6	-	6.6
Basin R	47	35.7	19%	5.7	54.2	17%	8.0
South Tidal	200	7.1	-2%	-0.1	13.1	0%	0.0
Confluence	300	6.0	-3%	-0.2	12.0	-2%	-0.3
North Tidal	400	10.6	69%	4.3	18.0	55%	6.4
Wetland (South)	500	4.4	2%	0.1	8.8	1%	0.1
Wetland (North)	600	2.8	7%	0.2	5.6	5%	0.3

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.6 East Park – Difference in Peak Discharge from Pre to Post: 2036 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin A	3	22.1	-6%	-1.3	48.2	-8%	-4.0
Basin B1 (NT)	2	26.0	-5%	-1.5	42.6	0%	-0.2
Basin B2 (NT)	-	-	-	-	-	-	-
Basin C1	1	47.8	13%	5.5	65.5	11%	6.6
Basin C2 (Spillway Only)	100	0.0	0%	0.0	1.7	-	1.7
Basin R	47	29.1	-3%	-0.9	53.5	16%	7.4
South Tidal	200	6.8	-5%	-0.4	12.7	-3%	-0.4
Confluence	300	4.7	-23%	-1.4	8.9	-27%	-3.4
North Tidal	400	9.6	54%	3.4	16.6	43%	5.0
Wetland (South)	500	4.4	2%	0.1	8.8	1%	0.1
Wetland (North)	600	6.4	143%	3.7	10.8	104%	5.5

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

East Park 2016 (2-Lane) (Table 5.4) results comparing pre-development to post development modeled results indicate that there is a decrease in peak discharge for all basins that discharge to non-tidal waters (Basin B1) for the 10-year and 100-year design storms (Note: Basin B2 discharges through Basin B1 before discharging to non-tidal waters). Decreases in peak discharge were also estimated for areas discharging to “South Tidal” and “Confluence”, which discharge to tidal waters. The increase in discharge from the other basins and drainage areas on-site that discharge to tidal waters is a result of the increase in impervious area on East Park under this scenario. In the 2016 scenario, the only construction done on East Park is the construction of the new 2-lane highway (minus the Richmond Hill Section), no other construction is proposed for the 2016 scenario.

Similar to the results of East Park 2016 (2-Lane), the results for East Park 2016 (4-Lane) (Table 5.5) comparing pre-development to post-development modeled results also indicate that there is a decrease in peak discharge for all basins that discharge to non-tidal waters (Basin B1) for the 10-year and 100-year design storms.

East Park 2036 (4-Lane) (Table 5.6) results comparing pre-development to post-development modeled results indicate that there is a decrease in peak discharge for the 10-year and 100-year design storms for all basins discharging to non-tidal waters (Basin B1). There is also a decrease in peak discharge for a number of the other basins and drainage areas discharging to tidal waters, including Basin A, Basin R and areas discharging to “South Tidal” and “Confluence”. During the 2036 proposed conditions, many basins experience a decrease in peak discharge, due to the decrease of impervious cover in the park. Under this scenario, the proposed conditions on East Park are built, and many of the existing impervious roadways are removed.

5.3.2 South Park

Table 5.7 and 5.8 displays a summary of the model results for peak discharge for each park outlet for South Park, under the two proposed condition models.

Table 5.7 South Park – Difference in Peak Discharge from Pre to Post: 2016/2036 (2-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin H (NT)	5	24.3	-34%	-12.8	61.4	-1%	-0.4
Basin J	7	6.1	-64%	-11.0	14.4	-58%	-20.0
Basin P	3	10.8	-57%	-14.3	22.4	-46%	-19.2
Center (NT)	10	10.9	0%	0.0	16.9	0%	0.0
North Central	12	6.8	1%	0.0	10.6	0%	0.1
East	19	15.1	0%	-0.1	23.5	0%	-0.1
South (NT)	20	10.9	-25%	-3.5	18.1	-19%	-4.2
Southwest (NT)	42	2.6	0%	0.0	5.6	0%	0.0
Northeast	43	4.3	-30%	-1.8	7.7	-26%	-2.7
SW Block (NT)	50	6.7	-1%	-0.1	11.0	-1%	-0.1

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.8 South Park – Difference in Peak Discharge from Pre to Post: 2016/2036 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin H (NT)	5	24.3	-34%	-12.8	61.4	-1%	-0.4
Basin J	7	6.1	-65%	-11.1	14.4	-58%	-20.0
Basin P	3	10.8	-57%	-14.3	22.4	-46%	-19.2
Center (NT)	10	10.9	0%	0.0	16.9	0%	0.0
North Central	12	6.8	1%	0.0	10.6	0%	0.1
East	19	15.1	0%	-0.1	23.5	0%	-0.1
South (NT)	20	10.8	-25%	-3.6	18.1	-19%	-4.2
Southwest (NT)	42	2.6	0%	0.0	5.6	0%	0.0
Northeast	43	5.7	-7%	-0.4	9.7	-6%	-0.6
SW Block (NT)	50	2.4	-64%	-4.3	4.9	-56%	-6.2

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

South Park 2016/2036 (2-lane) (Table 5.7) results comparing pre-development to post-development modeled results indicate that there is a decrease in peak discharge rates for the 10-year and 100-year design storms for all discharge points on-site except for the 10-year storm for the "North Central" discharge point. The North Central discharge point, which discharges to tidal waters shows a one percent increase for the 10-year storm. For the rest of the discharge points, the significant decrease in peak discharge during the 10-year and 100-year storm events is a result of a decrease in impervious area in the proposed conditions of the park.

South Park 2016/2036 (4-lane) (Table 5.8) results are similar to those for the 2-lane road comparing pre-development to post-development and indicate that there is a decrease in peak discharge rates for the 10-year and 100-year design storms for all discharge points on-site except for the 10-year storm for the "North Central" discharge point. For the rest of the discharge points, the significant decrease in peak discharge during the 10-year and 100-year storm events is a result of a decrease in impervious area in the proposed conditions of the park.

5.3.3 West Park

Tables 5.9 to 5.11 display a summary of the model results for peak discharge for each park outlet for West Park, under the three proposed condition models.

Table 5.9 West Park – Difference in Peak Discharge from Pre to Post: 2016 (2-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin K1	131	4.3	12%	0.5	11.0	31%	2.6
Basin K2	-	-	-	-	-	-	-
Basin L	90	55.5	-3%	-1.9	97.0	-1%	-1.3
Basin N (NT)	91	28.1	-16%	-5.2	55.1	-6%	-3.2
Basin O	183	22.9	2%	0.4	33.8	4%	1.5
Muldoon East	128	35.2	-17%	-7.3	56.5	-10%	-6.1
Muldoon West	-	-	-	-	-	-	-
South (NT)	95	18.5	-19%	-4.4	23.1	-26%	-8.3
Southwest	99	9.4	33%	2.3	17.6	-1%	-0.2
Northwest	122	11.7	19%	1.9	22.9	-8%	-1.9
North	128	20.3	-19%	-4.8	40.8	-18%	-8.7
Center Strip (NT)	176	17.4	-27%	-6.3	22.7	-54%	-26.9
South Strip (NT)	178	4.3	-54%	-5.0	15.5	-32%	-7.2
North Strip (NT)	179	13.0	-19%	-3.1	17.8	-55%	-21.4
Area M North (NT)	182	5.4	-74%	-15.0	10.5	-65%	-19.2
Area M South (NT)	184	19.4	-46%	-16.6	25.0	-49%	-24.3
Buildings	191	40.3	0%	0.0	59.8	1%	0.6

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.10 West Park – Difference in Peak Discharge from Pre to Post: 2016 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin K1	131	4.4	14%	0.5	11.1	32%	2.7
Basin K2	-	-	-	-	-	-	-
Basin L	90	55.5	-3%	-1.9	97.0	-1%	-1.3
Basin N (NT)	91	28.1	-16%	-5.2	55.1	-6%	-3.2
Basin O	183	22.9	2%	0.4	33.8	4%	1.5
Muldoon East	128	41.8	-2%	-0.8	64.3	3%	1.6
Muldoon West	-	-	-	-	-	-	-
South (NT)	95	18.5	-19%	-4.4	23.1	-26%	-8.3
Southwest	99	9.4	33%	2.3	17.6	-1%	-0.2
Northwest	122	11.7	19%	1.9	22.9	-8%	-1.9
North	128	29.7	18%	4.6	47.4	-4%	-2.1
Center Strip (NT)	176	18.0	-24%	-5.7	22.0	-56%	-27.6
South Strip (NT)	178	8.3	-11%	-1.0	15.7	-31%	-7.0
North Strip (NT)	179	16.4	2%	0.3	23.9	-39%	-15.3
Area M North (NT)	182	5.4	-74%	-15.0	10.6	-64%	-19.1
Area M South (NT)	184	20.4	-43%	-15.6	25.0	-49%	-24.3
Buildings	191	40.3	0%	0.0	59.8	1%	0.6

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

Table 5.11 West Park – Difference in Peak Discharge from Pre to Post: 2036 (4-lane)

Outfall Locations[1]	SWMM Outfall Node	10-Year, 24-Hour Storm			100-Year, 24-Hour Storm		
		Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)	Peak Discharge, Q (cfs)	% Change in Q	Total Change in Q (cfs)
Basin K1	131	3.8	-1%	0.0	9.7	16%	1.3
Basin K2	-	-	-	-	-	-	-
Basin L	90	40.7	-29%	-16.7	73.8	-25%	-24.5
Basin N (NT)	91	14.4	-57%	-18.9	29.3	-50%	-29.0
Basin O	183	4.9	-78%	-17.6	19.1	-41%	-13.2
Muldoon East	128	44.4	4%	1.9	62.9	0%	0.2
Muldoon West	-	-	-	-	-	-	-
South (NT)	95	11.3	-51%	-11.7	19.9	-37%	-11.5
Southwest	99	8.4	18%	1.3	16.2	-9%	-1.6
Northwest	122	11.1	-13%	-11.8	22.1	-11%	-2.7
North	128	22.5	-10%	15.4	62.8	27%	13.3
Center Strip (NT)	176	15.6	-34%	5.8	21.8	-56%	-27.8
South Strip (NT)	178	0.8	-91%	-22.9	4.2	-81%	-18.5
North Strip (NT)	179	15.1	-6%	5.8	23.5	-40%	-15.7
Area M North (NT)	182	3.1	-85%	-13.0	5.6	-81%	-24.1
Area M South (NT)	184	16.3	-55%	-4.1	24.4	-50%	-24.9
Buildings	191	25.6	-36%	-10.4	45.4	-23%	-13.8

[1] (NT) Indicates outfall discharges to non-tidal waters (i.e. all NYS SWM requirements must be met).

West Park 2016 (2-lane) (Table 5.9) results comparing pre-development to post-development modeled results indicates that there is a decrease of the 10-year, and 100-year peak discharge rates for discharge points discharging to non-tidal waters. Results showed an increase in peak discharge for the 10-year storm for Basin K1, Basin O, “Southwest”, “Northwest”, and “Buildings.” The increase in peak discharge in these areas is a result in the increase of impervious area due to the construction of the 2-lane road. Results showed a decrease for the 100-year storm for “Southwest” and “Northwest” when compared to the existing conditions. Results show an increase in peak discharge for the 100-year storm for Basin K1, Basin O and “Buildings.” Basin K1 indicates a 31% (2.60 cfs) increase in the peak discharge. This increase appears to be due to the increase in impervious area of the road, which passes through that section of the park. The discharge points which outlet to the non-tidal waters all meet NYS requirements by controlling the 100-year storm.

West Park 2016 (4-lane) (Table 5.10) results comparing pre-development to post-development modeled results indicates that there is a net decrease of the 10-year and 100-year peak discharges for all discharge points non-tidal waters. Results showed an increase in peak discharge for the 10-year storm for Basin K1, Basin O, “Southwest”, “Northwest”, “North” and “North Strip.” The increase in peak discharge in these areas is a result in the increase of impervious area due to the construction of the 4-lane road. Results showed a decrease for the 100-year storm for “Southwest,” “Northwest,” and “North Strip” when compared to the 10-year storm conditions. Results show an increase in peak discharge for the 100-year storm for Basin K1, Basin O and Muldoon East. Basin K1 indicates a 32% (2.70 cfs) increase in the peak discharge. Basin O results indicate a 4% (1.50 cfs) increase in peak discharge, which is due to the increase in impervious area. The discharge points which outlet to the non-tidal waters all meet NYS requirements by controlling the 100-year storm.

West Park 2036 (4-Lane) (Table 5.11) results comparing pre-development to post-development modeled results indicate that there is a net decrease of the 10-year and 100-year peak discharges for all discharge points except for Basin K1 (100-year), North (100-year) and Southwest (10-year). Results for Basin K1 indicate an increase of 16% (1.30 cfs) for the 100-year peak discharge. Results for North indicate an increase of 27% (13.3 cfs), which is primarily attributed to the development of this area. Results for Southwest indicate an 18% (1.30 cfs) for the 10-year storm, but a decrease in peak discharge for the 100-year storm. These discharge points discharge to tidal waters; therefore, a deviation from the NYS requirements for the increase in peak discharge to these areas is allowed.

5.3.4 Discussion of Findings

The results indicate that the requirements established by the State of New York were met for all proposed conditions in comparison to pre-development conditions. To meet channel protection volume requirements (24-hour extended detention for the 1-year, 24-hour storm event), all outlet structures for basins were designed to hold the water quality volume for 24-hours before being released. This was accomplished by modifying the outlet structures for all existing basins by raising the low-flow orifice to hold the water quality volume in a wet pond and adding a weir structure to provide extended detention.

The 100-year storm was safely conveyed with 1-foot of freeboard for all stormwater management basins in all Parks, as required by New York State Department of Environmental Conservation, Division of Water, Guidelines for Design of Dams. Also, all stormwater management proposed for the Fresh Kills Park, including swales and basins met all requirements stated in Part 360 of state regulations for solid waste management facilities which indicate that the stormwater management proposed must be designed and constructed to protect the cover from, at a minimum, the peak discharge of a 24-hour, 25-year frequency storm. The swales in the park system were designed to safely convey the 100-year storm event, without overflowing.

Based on the NYS requirements, it appears that several basins exceed the criteria and appear to be oversized. These basins include, Basins J and P on the South Park and Basins L, N and O on the West Park. It appears that since these basins were designed to meet the NYS requirements during construction, the capacity when the site is vegetated, no longer under construction, that these basins could all be reduced in size.

Post-development peak discharge rates were controlled down to pre-development rates for the 10-year and 100-year, 24-hour storm events for all locations that discharge to non-tidal waters.

Part II of the SWM Plan will update the models discussed in this report to include use of Low Impact Development technologies within the park system to further reduce peak flows and decrease the overall volume leaving the park system.

6. WATER QUALITY: MODEL APPROACH, INPUTS AND RESULTS

6.1 Introduction

Water quality modeling is used to estimate expected total annual loads of pollutants from a watershed. Pollutants of particular concern in stormwater quality modeling include total annual nitrogen (TN), total annual phosphorus (TP), total annual suspended solids (TSS), metals, and pathogens. These pollutants come from a number of different sources including, fertilizers, vehicles, unstabilized soils, and simply the natural degradation of organic matter in the environment. Storms resulting in runoff effectively route these pollutants directly to waterways. Once in waterways these pollutants have the potential to create a number of different problems including excessive vegetative growth oftentimes resulting in eutrophication, bioaccumulation in aquatic life, and degradation of aquatic communities (i.e., plants, fish, macroinvertebrates).

Stormwater quality modeling of TN, TP, and TSS annual loading was conducted for each park in the Fresh Kills Landfill redevelopment project. The purpose of this modeling effort was to estimate the annual and per acre loading of each of these pollutants to determine the level of pollutant removal required to meet water quality requirements and guide planning of the implementation of LID stormwater management techniques. The TN, TP, and TSS loading rates were calculated on an annual and annual per acre basis using the Simple Method.

6.2 Receiving Waters

The receiving waters of the Park system are as follows:

- North Park: Main Creek and Fresh Kills Creek;
- East Park: Main Creek and Richmond Creek;
- South Park: Richmond Creek and Fresh Kills Creek; and
- West Park: Arthur Kill waterway and Fresh Kills Creek.

The confluence of Main Creek and Richmond Creek is located near the southern side of the North Park. Downstream of the confluence, the stream is referred to as Fresh Kills Creek. Fresh Kills Creek ultimately discharges to the Arthur Kill waterway along the western site boundary. The Arthur Kill waterway is a shipping channel which forms the boundary between western Staten Island and New Jersey. The channel connects Raritan Bay to the south and Newark Bay to the north.

Title 6 of NYCRR Part 703 designates the Use Classification of Arthur Kill and the lower portion of Fresh Kills Creek as Class SD. This Use Designation requires that the water be suitable for fish survival, a classification reserved for water bodies that cannot meet the requirements for primary and secondary human contact and fish propagation. This use designation requires that dissolved oxygen must always exceed 3 mg/L (AKRF, 2007). The use classification of Richmond Creek, Main Creek, and the upper portion of Fresh Kills Creek require that the water be suitable for fish propagation and survival and for primary and secondary contact recreation (Use Class SC). Use Class SC requires that dissolved oxygen never be below 5 mg/L, fecal coliform monthly geometric means be less than or equal to 2,000 colonies per 100 mL, and total coliform monthly median be less than 2,400 colonies per 100mL (AKRF, 2007).

Sections of the Arthur Kill waterway are listed on New York's 2006 303(d)-list as impaired for floatables and fish consumption. The causes of the floatables listing of the waterway include urban land use, storm water runoff, and combined sewer overflows. The reasons for the fish consumption advisory include sediment contamination by PCBs, cadmium, and dioxin (NYDEC, 2006). The 303(d)-list is published by the New York Department of Environmental Conservation and "identifies those waters that do not support appropriate uses and that require development of a Total Maximum Daily Load (TMDL) or other restoration strategy to attain quality standards" (NYDEC, 2006).

6.3 Methodology

Approximate annual loads of total nitrogen, total phosphorus, and total suspended solids were determined for each of the four park areas using the Simple Method; a land use based loading model approach. To accomplish this, existing land cover layers were created by digitizing the land cover observed in the 2006-2007 one-foot aerial imagery provided by Rogers Surveying (2007). Proposed land cover for the South, East, and West Parks were determined based on the Draft Master Plan (dated 05/11/2007) and the 100 percent road alignments (1/27/08) from FO. Proposed land cover for the North Park was determined from the North Park Master Plan (dated 10/08/2007) and the 100 percent road alignments (1/27/08) from FO. For the purpose of calculating the water quality loading rates, land cover was divided into four categories: turfgrass, meadow and prairie, impervious cover, and woods. Tables 6.1 and 6.2 show the area and percentage of each land cover type in each Park for existing and proposed conditions.

Table 6.1 Existing Conditions Land Cover

Park Area	Drainage Type	Park Area		Impervious Cover		Woods		Meadow Prairie	
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
North	Basin	124.2	47.7%	8.1	35.3%	0.0	0.0%	116.1	57.1%
	No Basin	136.0	52.3%	14.8	64.7%	33.9	100.0%	87.2	42.9%
	Total	**260.2**		**22.9**	**8.8%**	**33.9**	**13.0%**	**203.4**	**78.2%**
South	Basin	125.7	59.5%	8.1	39.6%	0.0	0.0%	117.6	63.1%
	No Basin	85.7	40.5%	12.4	60.4%	4.6	100.0%	68.7	36.9%
	Total	**211.4**		**20.5**	**9.7%**	**4.6**	**2.2%**	**186.3**	**88.1%**
East	Basin	300.4	69.1%	22.1	72.2%	0.0	0.0%	278.3	68.9%
	No Basin	134.1	30.9%	8.5	27.8%	0.0	0.0%	125.6	31.1%
	Total	**434.5**		**30.7**	**7.1%**	**0.0**	**0.0%**	**403.9**	**92.9%**
West	Basin	578.4	87.0%	77.2	71.2%	69.1	94.0%	432.0	89.5%
	No Basin	86.1	13.0%	31.3	28.8%	4.4	6.0%	50.4	10.5%
	Total	**664.5**		**108.5**	**16.3%**	**73.5**	**11.1%**	**482.5**	**72.6%**
Fresh Kills Total	Basin	1128.7	71.9%	115.5	63.3%	69.1	61.7%	944.0	74.0%
	No Basin	441.9	28.1%	66.9	36.7%	42.9	38.3%	332.0	26.0%
	Total	**1570.6**		**182.5**	**11.6%**	**112.1**	**7.1%**	**1276.0**	**81.2%**

Cell represents the percentage of the land cover category draining or not draining to a stormwater basin.
Cell represents the area or percentage of the land cover category within each park.

Table 6.2 Proposed Conditions Land Cover

Park Area	Drainage Type	Park Area		Impervious Cover		Woods		Meadow Prairie		Turf	
		Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
North	Basin	168.5	65.0%	9.9	53.8%	28.1	31.7%	109.9	84.6%	20.7	91.9%
	No Basin	90.9	35.0%	8.5	46.2%	60.5	68.3%	20.0	15.4%	1.8	8.1%
	Total	**259.4**		**18.4**	**7.1%**	**88.6**	**34.1%**	**129.9**	**50.1%**	**22.5**	**8.7%**
South	Basin	110.1	52.1%	1.5	15.6%	0.0	0.2%	108.6	54.1%	0.0	0.0%
	No Basin	101.3	47.9%	8.0	84.4%	1.0	99.8%	92.3	45.9%	0.0	0.0%
	Total	**211.4**		**9.4**	**4.5%**	**1.0**	**0.5%**	**201.0**	**95.1%**	**0.0**	**0.0%**
East	Basin	299.8	68.9%	21.6	61.8%	3.1	0.0%	275.0	69.2%	0.0	0.0%
	No Basin	135.5	31.1%	13.4	38.2%	0.0	0.0%	122.2	30.8%	0.0	0.0%
	Total	**435.4**		**35.0**	**8.0%**	**3.1**	**0.7%**	**397.2**	**91.2%**	**0.0**	**0.0%**
West	Basin	454.0	68.5%	34.7	50.1%	4.3	25.8%	409.8	73.1%	5.1	31.0%
	No Basin	209.2	31.5%	34.6	49.9%	12.4	74.2%	150.8	26.9%	11.4	69.0%
	Total	**663.2**		**69.3**	**10.4%**	**16.7**	**2.5%**	**560.6**	**84.5%**	**16.6**	**2.5%**
Fresh Kills Total	Basin	1032.4	65.8%	67.7	51.3%	35.5	32.5%	903.3	70.1%	25.8	66.0%
	No Basin	536.9	34.2%	64.4	48.7%	73.9	67.5%	385.3	29.9%	13.3	34.0%
	Total	**1569.3**		**132.1**	**8.4%**	**109.5**	**7.0%**	**1288.6**	**82.1%**	**39.1**	**2.5%**

Cell represents the percentage of the land cover category draining or not draining to a stormwater basin.
Cell represents the area or percentage of the land cover category within each park.

Larger areas of more intense land uses such as impervious surfaces and turfgrass typically result in higher loading rates for total suspended solids, total nitrogen, and total phosphorus. Appendix A of the 2001 New York Stormwater Design Manual, the National Stormwater Quality Database, and data from the Philadelphia Department of Water were all consulted in the determination of appropriate runoff concentrations. The National Stormwater Quality Database uses the term "land use" because it tends to focus more on how the land is being used by humans as opposed to the ecological classification of the land. For the purposes of this study, the term land cover is used the vast majority of the park area is undeveloped and thus the focus was primarily the vegetative cover types with no further classification of developed land beyond impervious or not impervious. The land use categories used to represent the land cover types present on-site are detailed below.

Impervious cover runoff concentrations were all determined from the National Stormwater Quality Database land use classification for industrial land use. Meadow/prairie land cover runoff concentrations were determined from the runoff concentrations provided in the National Stormwater Quality Database land use classification for open space. Turf land cover runoff concentrations were determined from the runoff concentrations provided in the National Stormwater Quality Database land use classification for mixed open space. Wooded land cover runoff concentrations were determined from the runoff concentrations provided utilized in a 2005 Philadelphia Department of Water study (originally from Smullen, 1999) land use classification for wooded land. Figure 6.3 details typical runoff concentrations for the land cover types found at Fresh Kills Landfill. The concentrations shown are used in the annual loading calculation presented in Section 1.3.1. The New York Stormwater Design Manual was consulted, though for the sake of consistency, most runoff concentrations were obtained from the National Stormwater Quality Database.

Table 6.3 Runoff Concentrations by Land Cover Type

Land Cover Type	Total Suspended Solids	Total Nitrogen	Total Phosphorus
	(mg/L)	(mg/L)	(mg/L)
Meadow/Prairie	48.5[1]	0.74[1]	0.31[1]
Turfgrass[2]	83.5[1]	1.12[1]	0.27[1]
Woods[3]	40.5[2]	0.505[2]	0.15[2]
Impervious Area	78[1]	1.4[1]	0.26[1]

1. National Stormwater Quality Database (2004)
2. Philadelphia Department of Water (2005)

6.3.1 Simple Method for Pollutant Loading Modeling

The Simple Method, as outlined in Appendix A of the New York Stormwater Management Design Manual (dated October 2001), was used to estimate the pollutant loading from park areas.

The Simple Method uses the following equations to estimate pollutant loads for chemical constituents:

Annual Loading

$$L = 0.226 * R * C * A$$

Where: L = Annual load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration (mg/L)
A = Area (acres)
0.226 = Unit conversion factor

Runoff Volume

$$R = P * P_j * R_v$$

Where: R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (typically 0.9)
R_v = Runoff coefficient

Runoff Coefficient

$$R_v = 0.05+0.9I_a$$

Where: I_a = Impervious fraction
(NYDEC, 2001)

The Simple Method was used to determine the average annual loading for the existing and proposed conditions based on the cover types and runoff concentrations presented in Tables 6.1, Table 6.2, Table 6.3 and equations included above. The area of each land cover type was accounted for through the use of the annual loading equation detailed above. The annual runoff and unit conversion factor were multiplied by the sum of the products of the pollutant concentration and area of each land cover type. Following computation of the proposed pollutant loads, pollutant reduction attributed to the stormwater basins was also computed. Further details regarding the annual loading calculations are included in Attachment 11.

For the existing conditions analysis, the loading calculations were completed for each park by splitting the parks up into two areas: (1) areas draining to stormwater basins; and (2) areas draining off-site without first draining to a stormwater basin (e.g., areas adjacent to tidal wetland areas along park perimeters). Average annual loading was determined for the portion of each park draining or not draining to a stormwater basin; no reduction in loading was considered for existing landfill stormwater infrastructure. Although some treatment is most likely occurring from the existing detention basins, this was not accounted for in the analysis because these basins were not designed for water quality management in accordance with NYS DEC standards.

For proposed conditions, loading calculations were completed for each park by splitting the parks up into two areas: (1) areas draining to stormwater basins; and (2) areas draining off-site untreated. Under proposed conditions, all existing detention basins have been reconfigured with modified outlet control structures to be either wet ponds or wet extended detention ponds, in order to hold the water quality volume, as required by NYDEC (for a complete description of modifications to existing basins see Section 4). Simply by raising the elevation of the existing low flow orifice, the basins were modified to hold the water quality volume, which was calculated for each basin based on the drainage area imperviousness. In accordance with the NYS Design Manual, stormwater basins sized to hold the water quality volume have an average pollutant removal efficiency of 80% for TSS, 50% for TP, and 35% for TN; therefore meeting the water quality requirement of the NYDEC.

After the proposed conditions loading calculations were conducted for the park system, the NYS Design Manual removal efficiencies were multiplied by the pollutant loading values under proposed conditions to obtain the actual expected pollutant loading for to those areas of the park system that drain to stormwater basins. The loading was then recalculated to determine the proposed conditions annual pollutant loading incorporating the stormwater management basin pollutant removal efficiency.

6.4 Limitations

The values obtained in the following pollutant loading estimates should only be used to gain a rough estimate of the relative contribution each subcatchment is making to the total pollutant loading. The results provided below are useful for prioritizing subcatchments for stormwater management improvement, but are at too coarse of a scale for the design of specific BMPs or SMPs (Stormwater Management Practice, as referred to in the NY Design Manual) within each subcatchment. The Simple Method provides a reasonable estimate of expected pollutant loads associated with different land use development scenarios, but should not be used to make comparisons between subcatchments where there is only a minimal change in land use, impervious cover in particular (NYDEC, 2001).

Following further literature review, it was decided to use runoff concentration values provided in the New York Stormwater Management Design Manual, the National Stormwater Quality Database, and the Philadelphia Department of Water. As shown in Table 6.3, the pollutant loading values are based on the major on-site land cover types. Because of the extensive cap and dense vegetative cover on the majority of the site, it was assumed that the landfill runoff concentrations will vary little from sites with the same land cover types. The determination of site-specific pollution concentration estimates through stormwater quality monitoring was beyond the scope of this project.

6.5 Results

The following section briefly describes the results of the loading analysis. The total annual loading and per acre loading rates for existing and proposed conditions for each Park are included in Tables 6.4 and 6.5. See Attachment 11 for the complete existing and proposed pollutant loading tables.

Table 6.4 Existing Pollutant Loading by Park

Park Area	Drainage Type	Basin Area	Total Suspended Solids (lb/yr)		Total Nitrogen (lb/yr)		Total Phosphorus (lb/yr)	
		Acres	Total	Per Acre	Total	Per Acre	Total	Per Acre
North	Basin	124.2	6,632	53.4	103	0.8	40	0.3
	No Basin	136.0	9,765	71.8	148	1.1	52	0.4
	Total	*260.2*	*16,415*	*63.1*	*252*	*1.0*	*93*	*0.4*
South	Basin	125.7	6,686	53.2	104	0.8	41	0.3
	No Basin	85.7	7,876	91.9	124	1.4	44	0.5
	Total	*211.4*	*14,493*	*68.6*	*226*	*1.1*	*85*	*0.4*
East	Basin	300.4	17,294	57.6	269	0.9	105	0.3
	No Basin	134.1	7,071	52.7	110	0.8	43	0.3
	Total	*434.5*	*24,363*	*56.1*	*379*	*0.9*	*148*	*0.3*
West	Basin	578.4	49,465	85.5	769	1.3	272	0.5
	No Basin	86.1	18,618	216.2	306	3.6	90	1.0
	Total	*664.5*	*66,978*	*100.8*	*1,050*	*1.6*	*362*	*0.5*
Fresh Kills Total	Basin	1128.7	79,928	70.8	1,242	1.1	462	0.4
	No Basin	441.9	41,959	95.0	657	1.5	230	0.5
	Total	*1570.6*	*121,728*	*77.5*	*1,896*	*1.2*	*693*	*0.4*

Table 6.5 Proposed Pollutant Loading by Park

Park Area	Drainage Type	Basin Area	Total Suspended Solids (lb/yr)		Total Nitrogen (lb/yr)		Total Phosphorus (lb/yr)	
		Acres	Total	Per Acre	Total	Per Acre	Total	Per Acre
North	Basin	168.5	8,996	53.4	133	0.8	46	0.3
	No Basin	90.9	5,547	61.0	78	0.9	23	0.3
	Total	*259.4*	*14,661*	*56.5*	*213*	*0.8*	*71*	*0.3*
South	Basin	110.1	3,258	29.6	50	0.5	21	0.2
	No Basin	101.3	6,057	59.8	94	0.9	36	0.4
	Total	*211.4*	*9,260*	*43.8*	*143*	*0.7*	*57*	*0.3*
East	Basin	299.8	17,011	56.7	264	0.9	103	0.3
	No Basin	135.5	9,447	69.7	148	1.1	56	0.4
	Total	*435.4*	*26,439*	*60.7*	*412*	*0.9*	*159*	*0.4*
West	Basin	454.0	26,912	59.3	418	0.9	160	0.4
	No Basin	209.2	22,240	106.3	347	1.7	118	0.6
	Total	*663.2*	*48,736*	*73.5*	*758*	*1.1*	*279*	*0.4*
Fresh Kills Total	Basin	1032.4	56,098	54.3	863	0.8	330	0.3
	No Basin	536.9	42,882	79.9	659	1.2	232	0.4
	Total	*1569.3*	*98,851*	*63.0*	*1,520*	*1.0*	*565*	*0.4*

After the existing and proposed loading results were determined, the proposed loading was then recalculated to determine the proposed conditions annual pollutant loading incorporating the stormwater management basin pollutant removal efficiency, as described in Section 6.3.1. Table 6.6 presents the results of this analysis.

Table 6.6 Proposed Pollutant Loading with Reductions from Stormwater Basins

Park Area	Drainage Type	Basin Area	Total Suspended Solids (lb/yr)		Total Nitrogen (lb/yr)		Total Phosphoru (lb/yr)	
		Acres	Total	Per Acre	Total	Per Acre	Total	Per A
North	Basin	168.5	1,799	10.7	86	0.5	23	0.1
	No Basin	90.9	5,547	61.0	78	0.9	23	0.3
	Total	259.4	7,346	28.3	164	0.6	46	0.2
South	Basin	110.1	652	5.9	32	0.3	10	0.1
	No Basin	101.3	6,057	59.8	94	0.9	36	0.4
	Total	211.4	6,709	31.7	127	0.6	47	0.2
East	Basin	299.8	3,402	11.3	172	0.6	51	0.2
	No Basin	135.5	9,447	69.7	148	1.1	56	0.4
	Total	435.4	12,849	29.5	320	0.7	107	0.2
West	Basin	454.0	5,382	11.9	271	0.6	80	0.2
	No Basin	209.2	22,240	106.3	347	1.7	118	0.6
	Total	663.2	27,623	41.7	619	0.9	198	0.3
Fresh Kills Total	Basin	1032.4	11,220	10.9	561	0.5	165	0.2
	No Basin	536.9	42,882	79.9	659	1.2	232	0.4
	Total	1569.3	54,102	34.5	1,220	0.8	397	0.3

6.5.1 Existing Conditions

Under existing conditions, the West Park has the highest TSS, total nitrogen, and total phosphorus loading rates. The West Park contains nearly twice the impervious cover (16.3%) of any other park, mostly due to a large landfill operations facility located in the northern portion of the park. The TSS loading rate in the West Park is 100.8 lb/acre/year. The TN loading rates in the West Park is 1.6 lb/acre/year. The TP loading rates in the West Park is 0.5 lb/acre/year. The loading rates for areas draining to a stormwater basin as well as areas not draining to a stormwater basin are also higher in the West Park than any other park.

The proposed TSS, TN, and TP loading rates are lowest in the East Park. The East Park contains the lowest percentage (7.1%) of area which is impervious cover under existing conditions. Existing land cover in the East Park is dominated by meadow-prairie which has one of the lower pollutant runoff concentration values. The loading rates for areas draining to a stormwater basin as well as areas not draining to a stormwater basin are also lower in the South Park than any other park.

For comparison, the proposed TSS, TN, and TP annual loading rates for Fresh Kills in its entirety are 77.5 lb/acre/year, 1.2 lb/acre/year, and 0.4 lb/acre/year, respectively. While the per/acre loading rates are roughly comparible, it is important to note the area of the park draining to a stormwater basin and the number of basins serving each park area. A basin with a high pollutant loading and a small number of basins has a higher probability of being less effective at preventing sediment from leaving the site.

6.5.2 Proposed Conditions

Not Accounting for Removal by Stormwater Basins:

Under proposed conditions, the West Park has the highest TSS, total nitrogen, and total phosphorus loading rates. Under proposed conditions, the impervious cover in the West Park decreases by approximately six-percent, but still contains more impervious cover than any other park area. The TSS loading rate in the West Park is 73.5 lb/acre/year. The TN loading rate in the West Park is 1.1 lb/acre/year. The TP loading rates in the West Park is 0.4 lb/acre/year. The loading rates for areas draining to a stormwater basin as well as areas not draining to a stormwater basin are also equal or higher in the West Park than any other park.

The proposed TSS, TN, and TP loading rates are lowest in the South Park. Impervious cover in the South Park decreases from 9.7% to 4.5%, making it the park area with the lowest percentage of impervious cover under proposed conditions. Under proposed conditions, land cover in the South Park is dominated by meadow-prairie. The loading rates for areas draining to a stormwater basin as well as areas not draining to a stormwater basin are also lower in the South Park than any other park.

For comparison, the proposed TSS, TN, and TP annual loading rates for Fresh Kills in its entirety are 63.0 lb/acre/year, 1.0 lb/acre/year, and 0.4 lb/acre/year, respectively.

Accounting for Removal by Stormwater Basins:

Once pollutant removal by stormwater management basins is factored in, the total TSS, TN, and TP loads continue to be the highest in the West Park. Factoring in the 80% TSS reduction, 50% TP reduction, and 35% TN reduction resulting from retention of the water quality volume in the stormwater management basins, the pollutant loading values are as follows. The TSS annual loading rate in the West Park is 41.7 lb/acre/year. The TN annual loading rate in the West Park is 121.8 lb/acre/year. The TP annual loading rate in the West Park is 0.3 lb/acre/year. After factoring in pollutant removal by basins, the South Park continues to have the lowest annual pollutant loading rates.

After reductions from basins, the total nitrogen and total phosphorus annual loading rates (on a per acre basis) in the West Park are comparable to the loading rates for the North, South, and East parks. The West Park, per acre suspended solids loading rate is still approximately 25% higher than the North, East and South Parks.

For comparison, the proposed TSS, TN, and TP annual loading rates for Fresh Kills in its entirety are 34.5 lb/acre/year, 0.8 lb/acre/year, and 0.3 lb/acre/year, respectively.

Discussion

The overall annual loading of TSS decreased from 121,728 lb/year under existing conditions to 98,851 lb/year under proposed conditions (without stormwater basin removal), and 19,770 lb/yr (with stormwater basin removal). The overall loading of total nitrogen decreased from 1,896 lb/year under existing conditions to 1,520 lb/year under proposed conditions (without stormwater basin removal), and 988 (with stormwater basin removal). The overall loading of total phosphorus decreased from 693 lb/year under existing conditions to 565 lb/year under proposed conditions (without stormwater basin removal), and 283 lb/yr (with stormwater basin removal).

The areas draining to stormwater management basins and not draining to stormwater management basins changed between existing and proposed conditions due to the divisions created by new roads and swales. Table 6.7, 6.8, and 6.9 summarize the TSS, total nitrogen, and total phosphorus loading for each park, respectively. These tables are useful for providing an overall view of the contribution each park area is making to the total loading for the project, but are at too coarse of a scale to use for design purposes.

Table 6.7 Total Annual TSS Loading Per Park

Park Area	Existing TSS Loading	Proposed TSS Loading (without ponds)	Proposed TSS Loading (with ponds)	Percent Difference (Existing to Proposed) (without ponds)	Percent Difference (Existing to Proposed) (with ponds)
	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
North	16,415	14,661	7,346	(-10.68%)	(-55.25%)
South	14,493	9,260	6,709	(-36.11%)	(-53.71%)
East	24,363	26,439	12,849	8.52%	(-47.26%)
West	66,978	48,736	27,623	(-27.24%)	(-58.76%)
Total	**121,728**	**98,851**	**54,102**	**(-18.79%)**	**(-55.56%)**

Table 6.8 Total Annual Total Nitrogen Loading Per Park

Park Area	Existing Total Nitrogen Loading	Proposed TN Loading (without ponds)	Proposed TN Loading (with ponds)	Percent Difference (Existing to Proposed) (without ponds)	Percent Difference (Existing to Proposed) (with ponds)
	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
North	252	213	164	(-15.36%)	(-34.81%)
South	226	143	127	(-36.81%)	(-43.99%)
East	379	412	320	8.68%	(-15.61%)
West	1,050	758	619	(-27.81%)	(-41.06%)
Total	**1,896**	**1,520**	**1,220**	**(-19.85%)**	**(-35.67%)**

Table 6.9 Total Annual Total Phosphorous Loading Per Park

Park Area	Existing Total Phosphorus Loading	Proposed TP Loading (without ponds)	Proposed TP Loading (with ponds)	Percent Difference (Existing to Proposed) (without ponds)	Percent Difference (Existing to Proposed) (with ponds)
	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
North	93	71	46	(-23.75%)	(-50.22%)
South	85	57	47	(-33.12%)	(-45.37%)
East	148	159	107	7.43%	(-27.29%)
West	362	279	198	(-22.87%)	(-45.43%)
Total	**693**	**565**	**397**	**(-18.46%)**	**(-42.73%)**

6.6 Summary

Total nitrogen, phosphorus, and suspended solids loading rates are driven by impervious cover in each drainage area, but are ultimately a function of many different factors including the expected runoff (a function of impervious cover) and the complete land cover composition of the drainage area. TSS removal under proposed conditions (without basin removal) amounted to a 19% decrease for the entire park area and ranged from a 36% decrease to an 8% increase for each park area. TN removal under proposed conditions (without basin removal) amounted to a 20% decrease for the entire park area and ranged from a 37% decrease to a 9% increase for each park area. TP removal under proposed conditions (without basin removal) amounted to an 18% decrease for the entire park area and ranged from a 33% decrease to a 7% increase for each park area. The increase in pollutant loading under proposed conditions can likely be attributed to the increasing number of roads in the East Park.

However, once pollutant removal from the basins is factored, the annual loads decrease by 16% and more. TSS removal under proposed conditions (with basin removal) amounted to a 56% decrease for the entire park area and ranged from a 47 to 59% decrease for each park area. TN removal under proposed conditions (without basin removal) amounted to a 36% decrease for the entire park area and ranged from a 16 to 44% decrease for each park area. TP removal under proposed conditions (without basin removal) amounted to an 43% decrease for the entire park area and ranged from a 27 to 50% decrease for each park area.

Stormwater basins provide a good deal of pollutant removal, but further improvements can still be made by strategically reducing areas of impervious cover and installing additional stormwater management controls up-stream of the basins. Section 6.7 discusses the stormwater controls which can be utilized to either replace or mitigate the impacts of impervious surfaces or other high intensity land cover surfaces. Part II of the Stormwater Management Plan will detail the specific pollutant removals expected at from each Fresh Kills Landfill.

6.7 Pollutant Removal by LID Controls

It is important to note that the total nitrogen, phosphorus, and total suspended solids loads presented in this report do not take into account pollutant removal by the proposed LID controls. LID controls such as rain gardens, vegetated swales, and treatment wetlands are highly effective at removing nitrogen, phosphorus, and suspended solids. In Part II of the SWM Plan, LID controls will be implemented to target areas which are known to be significant contributors to the total nitrogen, phosphorus, and suspended solids loads such as proposed parking lots and roofs. Additionally, all proposed stormwater swales will be grassed or vegetated to further enhance the site's TSS removal capabilities. LID stormwater controls will be used to the fullest extent possible to ensure that nitrogen, phosphorus, and suspended solids loads in the site's outfalls are less than existing levels both during and after construction. Attachment 5 shows the target areas for each of the proposed stormwater controls. Based on these improvements, the pollutant loading results in this section will be revised in Part II of the report, to account for the enhance pollutant loading capabilities of the LID technologies.

Table 6.10 provides a list of the proposed BMPs and the typical removal efficiency of each BMP (i.e., SMP). The removal efficiencies presented are ideal pollutant removal rates. Factors such as site constraints, hydrology, and BMP installation can all significantly impact actual pollutant removal efficiency. In many instances, BMPs will operate in series to provide multiple levels of treatment.

Table 6.10 Typical Removal Efficiencies for BMPs

BMP	Typical Percent Removal		
	TSS	**TN**	**TP**
Bioretention cell	85	40	60
Constructed wetland	80	30	50
Dry well	90	50	70
Grass/vegetated filter strips	85	40	60
Grass swale	85	50	40
Green roof	85	40	60
Infiltration trench	90	50	70
Planter box	85	50	70
Pocket wetland	80	30	50
Porous pavement	90	50	70
Raingarden	80	30	50
Riprap inlet filter ring	85	40	60
Riprap outlet protection	85	40	60
Slope stair stepping	85	50	40
Stormwater basin	80	35	50
Vegetated treatment swales	85	50	40

1. Percent pollution removal estimates were all obtained from Table A.4 in Appendix A of the 2001 NYSWDM.
2. Table A.4 was based on data provided in the National Pollutant Removal Database Revised Edition (Winer, 2001)

LID stormwater controls described in Table 6.10 will be incorporated into proposed conditions SWMM modeling in Part II of the SWM Plan. The purpose of incorporating the LID controls into the proposed conditions is to determine expected flows into the stormwater basins with the LID controls installed. The results of the modified proposed conditions modeling will be combined with the expected pollutant removal efficiency of the proposed BMPs to determine the expected pollutant removal, above and beyond what is required by NYS DEC.

7. CONCLUSIONS

The results of the analysis for Part I of the SWM Plan indicate that all NYS stormwater quality and stormwater quantity requirements were met and in many cases exceeded for all proposed conditions for each Park watershed. All outlet structures for stormwater management basins were designed, at a minimum, to provide extended detention for the 1-year, 24-hour design storm, as required for water quality management. For all areas discharging to non-tidal waters, a decrease in the post-development 10-year and 100-year, 24-hour storm event peak discharges was achieved, as required. Additionally, multiple areas discharging to tidal waters also met these criteria, which is not required by NYS but provides additional peak control and water quality benefits above and beyond those required by NYS. Also, for all stormwater management basins, the 100-year, 24-hour design storm event was safely conveyed with a minimum of one-foot of freeboard provided in each basin.

A pollutant loading analysis was also completed for each park. The results of the loading analysis indicate that in general, the total annual loading of total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP) will decrease following build-out, due to the overall decrease in impervious area on-site. Additionally, with the modifications to the existing stormwater ponds, the ponds provide additional load reduction for a total annual load reduction of 67,626 lb/year for TSS, 676 lb/year for TN and 296 lb/year for TP as compared to existing conditions for the park system overall.

The estimated peak discharge rates and volume of stormwater discharging off-site, as well as the estimated pollutant annual loading rates for the development of Fresh Kills Landfill into Fresh Kills Park can be further minimized by the use of Low Impact Development technologies. The focus of Part II of the SWM Plan is to develop and model proposed conditions of the park system to meet additional stormwater criteria and project objectives, not required under NYS regulations, by incorporating Low Impact Development into the stormwater management design of the park system. Individual Stormwater Best Management Practices or BMPs will be added to the proposed site plans and the models will be modified to include these practices.

7.1 Future Modeling Work

Flow data collected from site specific rainfall events is necessary to ensure that the model is accurate and can be calibrated to predict future conditions. A site monitoring plan was submitted to FO on October 17, 2007 which outlined the installation schedule, monitoring equipment, monitoring locations and the proposed installation of the equipment at the Project site. North Park and East Park were proposed to be equipped in March 2008, with installation of monitoring equipment installed on the other Parks as a separate task.

The following monitoring equipment was proposed:

- Eleven (11) water level meters,
- Thirteen (13) area-velocity meters, and

- Four (4) rain gauges.

Water level meters were proposed for all basins associated with the North and East Parks, and in other areas (to be determined while on-site) where water level readings are believed to assist in model calibration. Area-velocity flow meters were proposed at culverts throughout the North and East Parks. The area velocity flow meters will be installed at the outlet of culverts and will be secured to the culvert using clips and bolts. Two rain gauges will be installed at both the North Park and the East Park. One rain gauge will be installed at a low elevation (near service/maintenance building) and one at a high elevation (top of landfill). All monitoring equipment will be set to collect data every minute. Based on rain events and weather patterns, data will be collected periodically, for use in calibration of the hydrologic model.

It is also necessary to obtain the exact elevations for each pond riser pipe. These were approximated for the purposes of this model.

Once this calibration data is available, the North and East Park models will be re-run and appropriately calibrated. Once the models have been calibrated, the South and West Parks can be modified in the same way. This modeling technique will provide a much more accurate representation of the way stormwater behaves on the Project site.

8. REFERENCES

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