PATHOGEN WATER QUALITY MODEL (PWQM)
QUALITY ASSURANCE PROJECT PLAN (QAPP)

Prepared on behalf of the NJ CSO Group Permittees
By Passaic Valley Sewerage Commission

Passaic Valley Sewerage Commission
Essex County
600 Wilson Avenue
Newark, New Jersey

"Protecting Public Health and the Environment"

~~May 19, 2016~~

Revised 1/14/2017

SECTION A – PROJECT MANAGEMENT

A.0 Summary of Changes

This Quality Assurance Project Plan (QAPP) is for the Pathogen Water Quality Model development to be performed by the NJ CSO Group. This QAPP describes the work necessary to update the existing Harbor Estuary Program (HEP) Pathogen TMDL model, and to recalibrate and revalidate the updated model to be used in the development of a CSO Long Term Control Plan (LTCP), should the participating members of the NJ CSO Group, as identified herein, decide to employ the Demonstrative Approach to their LTCP. In future versions, this section will include summaries of changes and when they were incorporated as appropriate.

March 19, 2016: Submitted QAPP to NJDEP for comment.

Revised January 14, 2017: Modified QAPP to address comments made by NJDEP in a letter dated November 14, 2016. Attachment C includes a copy of the November 14, 2016 letter. The following pages in this document have been changed to address NJDEP comments and the changes are either summarized below or shown in redline-strikeout.

a) **DEP Comment 1, pages 4 and 7 – The signatory for the Office of Quality Assurance was replaced with Biswarup Guha of the Bureau of Environmental Analysis, Restoration and Standards (BEARS).**

b) **DEP Comment 1, page 9 – Marc Ferko was replaced with Biswarup Guha on the Program Contact Information.**

c) **DEP Comment 2, page 17 – The role of the Model Evaluation Group (MEG) was clarified as addressing the question of whether the calibrated model will be technically defensible for DEP to rely upon it for regulatory decision-making. The role of DEP in the MEG was also clarified to state that DEP representatives would be invited to future MEG meetings and encouraged to participate.**

d) **DEP Comment 3, page 19 – The phrase "last CSO general permit" was replaced with "2004 master general CSO permit."**

e) **DEP Comment 4, page 22 – The phrase "Since existing and potential pathogen water quality standards are based on a 30-day geometric mean basis…" with "Since *some* existing and potential pathogen water quality standards are based on a 30-day** geometric mean…" and text was added to state that the model should reasonably reproduce the timings, duration and magnitudes of the ambient data.

f) DEP Comment 5, page 22 - The following was added to the relative error discussion: "Varied timeframes for these 'measures-of-fit' or other tests identified during model calibration and validation will be applied as necessary/recommended."

g) DEP Comment 6, page 23 – The discussion of electronic file transfers was clarified to commit to providing DEP with model executables and the input and output files.

h) DEP Comment 7, page 25 – The QAPP was not modified. The information requested will be included in the final report outlined in Section C3 of the QAPP under Section IVb.

i) DEP Comments 8 and 9, page 28 – The discussion of landside modeling was deleted. Only the commitment to following the approved methodology in the System Characterization QAPPs remains.

j) DEP Comment 10, page 28 – The discussion of stormwater loadings was clarified to commit to the landside QAPPs.

k) DEP Comment 11, page 29 – The universe of stations that will be considered for calibration and validation were included. The calibration will be based on the Compliance Monitoring QAPP stations and the ongoing NJHDG sampling during the calibration period. Model validation will be based primarily on NJHDG data. Other sources of data for the validation period will be identified when the validation period is chosen.

l) DEP Comment 12, page 31 – The heading in Table 4 was changed from "Future Influences" to "Potential Future Influences" to clarify that model projection conditions have not yet been chosen.

m) DEP Comment 13, page 31 – Language was added to the discussion of Baseline and Projection scenarios indicating that an analysis of rainfall records from NJ sites will be used to establish appropriate precipitation patterns to be used.

n) DEP Comment 14, page 35 – Table 5 was not modified. The information requested will be included in the final report outlined in Section C3 of the QAPP under Section IVd.

o) DEP Comment 15, page 36 – The hydrodynamic model discussion was updated to clarify that the model domain will end at USGS gage locations and that flow data from these will be used as model inputs.

p) **DEP Comment 16, page 36 – The phrase "illicit connections and/or undocumented dry weather inflows of pathogens" was replaced with "unidentified pathogen loads."**

q) **DEP Comment 17, page 37 – A statement was added to the Reconciliation with User Requirements section to affirm that all data collected will be included in the database with suspect data that were not used to assess the model calibration flagged as such.**

r) **Replaced "PWM" with "PWQM" as abbreviation for Pathogen Water Quality Model where it was used.**

s) **Updated text and Table 2 on Page 25 to accurately and consistently describe model grid sizes.**

A.1 Title of Plan and Approval

Title: Quality Assurance Project Plan, Pathogen Water Quality Modeling for the NJ CSO Group

Preparer:

Modeling Project Manager:	Timothy J. Groninger, HDR	5/2/2016 Date
Modeling QA Officer:	Stephen Ertman, Ph.D., HDR	5/2/2016 Date

PVSC LTCP Consultants:

LTCP Consultant Project Officer:	Michael J. Hope, P.E., Greeley & Hansen	5/4/16 Date
LTCP Consultant QA Officer:	Timothy J. Dupuis, P.E., CDM Smith	5/4/16 Date

Passaic Valley Sewerage Commission:

PVSC Program Manager:	Bridget McKenna, Chief Operating Officer, PVSC	05/04/2016 Date
PVSC QA Officer:	Marques Eley, PVSC	5/5/2016 Date

New Jersey Department of Environmental Protection

DEP Permits:

Joseph Mannick, CSO Coordinator — Date

DEP ~~QA:~~ BEARS

~~Mark Ferko, Office of Quality Assurance~~ — Date
Biswarup Guha, Bureau of Environmental Analysis, Restoration and Standards (BEARS)

Title: Quality Assurance Project Plan, Pathogen Water Quality Modeling for the NJ CSO Group

NJPDES Certification

"I certify that I am participating in the effort led by the New Jersey CSO Group to develop a well calibrated and validated water quality pathogen water quality model developed for potential use in the development of a Long Term CSO Control Plan for CSO impacted waters in New Jersey. I understand that the model development work is to be performed in accordance with this QAPP. Although I may not have the particular expertise required to fully understand or direct the work described herein, I agree to fully cooperate in such efforts and acknowledge my consent to permit the NJDEP, PVSC and PVSC's Modeling Evaluation Group to provide the necessary input and review of the work described in the QAPP."

05/04/2016
Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewage Commission

5.5.16
Timothy Boyle — Date
Exec. Director ~~MUA~~, City of Bayonne

5/5/16
Frank Pestana — Date
Licensed Operator, Borough of East Newark

5/5/16
Rocco Russomano — Date
Town Engineer, Town of Harrison

6/1/16

Rich Haytas
Senior Engineer, Jersey City MUA

Date

5/27/16

Date

Gerry Kerr
DPW Superintendent, Town of Kearny

5-9-16

Ras J. Baraka
Mayor, City of Newark

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5/5/16

Frank Pestana
Exec. Director, North Bergen MUA

Date

5/3/16.

Manny Ojeda
Director Public Works, City of Paterson

Date

5/25/16

Samuel McGhee
Executive Director, Joint Meeting of Essex and Union Counties

Date:

5/18/2016

Richard L. Fitamant
Executive Director, Middlesex County Utilities Authority

Date:

5/5/16

Frank Pestana
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Alfred R. Restaino
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Date

Quality Assurance Project Plan

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Alfred R. Restaino

Date

Jessie V. D'Amore
Superintendent, City of Hackensack
Date 06/07/16

Superintendent, City of Hackensack

Superintendent, Ridgefield Park Village 5/25/16

Superintendent, Ridgefield Park Village 5/25/16

Daniel Loomis, P.E.
City Engineer, City of Elizabeth
Date

5/25/16
Luis Perez-Jimenez
Director of Water Operations, Perth Amboy City
Date

New Jersey Department of Environmental Protection

DEP
Permits:

Joseph Mannick, CSO Coordinator — Date

DEP ~~QA:~~
BEARS

~~Mark Ferko, Office of Quality Assurance~~ — Date
Biswarup Guha, Bureau of Environmental Analysis, Restoration and Standards (BEARS)

Title: Quality Assurance Project Plan, Pathogen Water Quality Modeling for the NJ CSO Group

NJPDES Certification

"Without prejudice to any objections timely made to permit conditions, I certify that members of the Bergen County Utilities Authority (BCUA) are participating in the effort led by the New Jersey CSO Group to develop a well calibrated and validated water quality pathogen water quality model developed for potential use in the development of a Long Term CSO Control Plan for CSO impacted waters in New Jersey. I understand that the model development work is to be performed in accordance with this QAPP. Although I may not have the particular expertise required to fully understand or direct the work described herein, I endorse this effort and acknowledge my consent to permit the NJDEP, PVSC and PVSC's Modeling Evaluation Group to provide the necessary input and review of the work described in the QAPP."

Robert Laux — Date 5/19/16
Executive Director, BCUA

A.2 Distribution List

Passaic Valley Sewerage Commission

Bridget McKenna

Marques Eley

Other Entities Participating by Associated Sewage Treatment Plant

Passaic Valley Sewerage Commission (PVSC): Paterson; Newark; Kearny; Harrison; Bayonne MUA; Jersey City MUA; North Bergen MUA

Bergen County Utility Authority (BCUA): Ridgefield Park; Fort Lee; Hackensack

Joint Meeting of Essex and Union Counties: Elizabeth City

North Bergen MUA – Woodcliff Plant: North Bergen Township; Guttenberg; Union City

North Hudson Sewerage Authority (NHSA) - River Road STP: Weehawken; West New York; Union City

North Hudson Sewerage Authority (NHSA) –Adams Street STP: Hoboken

Middlesex County Utilities Authority (MCUA): Perth Amboy

New Jersey Department of Environmental Protection

Marzooq Alebus, Surface Water Permitting

Nancy Kempel, Surface Water Permitting

Dwayne Kobesky, Surface Water Permitting

Joseph Mannick, Surface Water Permitting

A.3 Program Contact Information

Contact information for those parties involved in the Pathogen Water Quality Modeling Program is as follows:

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A.4 Table of Contents

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LIST OF ~~FIGURES~~ATTACHMENTS

A.5 Project Organization

This pathogen water quality modeling QAPP details the work to be performed to enhance the HEP Pathogen TMDL model to develop the Pathogen Water Quality Model (PWQM) for New York-New Jersey Harbor and its surrounding major tributaries, which could be used for the development of CSO LTCPs using the Demonstration Approach. The modeling QAPP discusses data reliability, calibration methods, basis of input loads, and other information pertinent to supporting the proposed model enhancements necessary for the CSO program.

The development and application of the Pathogen Water Quality Model (PWQM) is anticipated to be executed by HDR Engineering Inc. (Mahwah, NJ) under subcontract to Greeley & Hansen. HDR does not intend to rely on subcontractors or independent consultants to support the modeling effort but if they do, such subcontractors or consultants would be subject to the processes and quality objectives defined by this QAPP. Further, any cooperating NJ CSO Group members that rely on the model output to satisfy CSO stipulations in their respective NJPDES permits remain fully responsible for permit compliance. Acceptance of the QAPP and its execution by cooperating members of the program is implied by signature on the Approval Page.

A.5.1 Key Individuals and Responsibilities

The organizational aspects of the PWQM development provide the framework for conducting the specified tasks. They can also facilitate project performance and adherence to quality control (QC) procedures and quality assurance (QA) requirements. Key project roles are filled by those persons responsible for ensuring the use of valid data and the person(s) responsible for approving and accepting final products and deliverables. The program organization includes relationships and lines of communication among all participants and data users. The signature on the Approval Page associated with each position names the specific individual responsible for the role as defined below:

Program Manager (PM)

Bridget McKenna, Chief Operating Officer at PVSC is the Program Manager. She is responsible for the overall oversight of PVSC's CSO program, including development of a Long-Term CSO Control Plan based in part on the results of the PQWM She will work with the Modeling Project Manager at HDR to ensure that project objectives are attained. In addition, the Program Manager will have the following responsibilities:

- Acting as primary point of contact at PVSC for NJDEP, the NJ CSO Group, and other stakeholders;

- Facilitating interaction between the Water Quality Modeling Program and other PVSC CSO Program contractors, reviewers, and other participants

- Reviewing and approving the project work plan, QAPP, the technical approach, and other materials developed to support the project to ensure technical quality and contract adherence;

- Appointing the QA Officer, and ensuring that documents/products are presented to him or her in a timely manner for review; and

- Fiscal accountability to PVSC.

LTCP Project Officer (PO) – Michael J. Hope, P.E., Greeley & Hansen

The Project Officer is responsible for the overall oversight of PVSC's CSO program, including development of a Long-Term CSO Control Plan based in part on the results of the PQWM. In addition, the Program Manager is responsible for:

- Taking corrective actions for any quality control (QC) problems with personnel, technical content, or procedures;

- Presenting documents/products to the PVSC Quality Assurance (QA) Officer;

- Fiscal accountability to PVSC;

- Tracking and maintaining compliance with applicable EPA and NJDEP procedures; and

- Coordinating and confirming the availability of team resources.

LTCP Quality Assurance Officer (QAO) – Timothy J. Dupuis, P.E., CDM Smith

The QAO has the following responsibilities:

- Confirming that the requirements of the QAPP are implemented through effective organizing and planning to meet the program and quality objectives;

- Monitoring and auditing QA/QC processes and performance;

- Approving the QAPP;

- Verifying that all data products are reviewed and approved according to accepted policies and guidelines before being released;

- Conducting an independent QA review of data and completed draft documents;

- Communicating any problems to the Program Manager; and

- Maintaining the official QAPP.

Modeling Project Manager

Tim Groninger will be the HDR Project Manager, and will be accountable for the overall performance and technical content of the modeling and monitoring deliverables and the quality of the associated services provided to PVSC and the Long Term Control Plan consultants (Greeley & Hansen/CDM Smith) during the performance of the modeling project. He is also responsible for communicating with PVSC regarding the progress of the work, and for ensuring that appropriate and sufficient resources are available to meet the project goals. The HDR Project Manager will be responsible for planning, directing, and controlling the work assignment tasks and ensuring the progress is commensurate with the project budget and schedule, and will communicate with PVSC for reviewing all interim and final products, will prepare written correspondence to NJDEP on PVSC's behalf, and will address deviations from schedule, budget or work quality. Specific responsibilities of the HDR Project Manager include the following:

- Acting as primary point of contact at HDR for PVSC;

- Providing support to PVSC in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements of the study design objectives are met;

- Preparing or reviewing preparation of project deliverables, including the QAPP and other materials developed to support the project, and ensuring deliverables are distributed to all appropriate project personnel;

- Reporting any quality problems to the QA Officer (QAO), and implementing corrective actions to ensure completion of high-quality projects within established budgets and time schedules.

Modeling Task Leader

Rich Isleib will be the HDR Water Quality Modeling Task Leader, and will be accountable for the technical content of the modeling deliverables including the development, calibration and validation of the hydrodynamic and pathogen modules of the PQWM. The Water Quality Modeling Task Leader will be responsible for controlling the direction of all aspects of the technical water quality modeling work elements and ensuring the quality of both interim and final products. Specific responsibilities of the HDR Water Quality Modeling Task Leader include the following:

- Managing the day-to-day execution of modeling activities by ensuring the availability of team resources, coordinating assignments, establishing priorities, scheduling, etc.;
- Providing guidance, technical advice, and performance evaluations to those assigned to the project;
- Working directly with the Modeling Quality Assurance Officer and the Model Evaluation Group to assure high quality results.

Modeling Quality Assurance Officer (QAO)

Steve Ertman will be the Modeling Quality Assurance Officer (QAO) at HDR and will monitor the technical management of the project, and assure the implementation of any recommendations resulting from the Model Evaluation Group's technical review. The QAO will be responsible for coordinating all QA activities and for ensuring that activities related to model code, model inputs, model execution, and interpretation of results are conducted in accordance with the QAPP. The QAO is an oversight and review position who has independence from the data generating and modeling staff, and has the following responsibilities:

- Approving and maintaining the official QAPP;
- Ensuring that the requirements of the QAPP are implemented through effective organizing and planning to meet the program and quality objectives;
- Monitoring and auditing QA/QC processes and performance;
- Ensuring that all model outputs are reviewed and approved according to accepted policies and guidelines before being released;

- Conducting an independent QA review of model simulations and completed draft documents;

- Coordinating the Model Evaluation Group and ensuring their feedback is incorporated into model processes; and

- Communicating any problems to the Modeling Project Manager.

Water Quality Modeling Staff

HDR modeling staff will be responsible for the development of model input data, revisions to the water quality model code and schematization, validation and/or re-calibration, and projections using the validated model, as well as writing a final modeling report.

Model Evaluation Group (MEG)

Because the updated model framework will be used by NJDEP for regulatory decision-making related to ~~assess~~ the attainment of bacteria water quality criteria ~~related to bacteria~~, a MEG will be assembled by PVSC to ensure that the calibrated model will be technically defensible ~~review~~ and to assess how well the modeling project has met quality assurance objectives in keeping with the EPA's Guidance on the Development, Evaluation, and Application of Environmental Models (EPA/100/k-09/003, March 2009). The MEG will be organized by PVSC under advisement from NJDEP, who will be invited to attend MEG meetings and will be encouraged to participate. The MEG review may include comments on the following project elements:

- Appropriateness of input data;

- Appropriateness of boundary condition specifications;

- Documentation of inputs and assumptions;

- Applicability and appropriateness of selected parameter values;

- Documentation and justification for adjusting model inputs to improve model performance (calibration);

- Model application with respect to the range of its validity; and

- Supporting empirical data that strengthen or contradict the conclusions that are based on model results.

It should be noted that the water quality model to be modified and run under the present QAPP will be based on the Harbor Estuary Program (HEP) model, which has been developed and vetted under previous harbor-wide efforts. Thus, the MEG review may only address the scope elements that result in modifications to the model skill and applicability.

MEG Members and responsibilities are provided below:

- Professor Steven Chapra, PhD, Tufts University – Oversight and input on all aspects of pathogen water quality modeling including modeling kinetics, levels of calibration and validation and future condition model applications.

- Professor Alan F. Blumberg, PhD, Stevens Institute - Oversight and input on all aspects of hydrodynamic modeling including physics of water circulation and mixing, levels of calibration and validation and future condition model applications.

- Wayne Huber, PhD, Oregon State University - Oversight and input on all aspects of watershed modeling including development of watershed level non-point source models and CSO sewer system models, levels of calibration and validation and future condition model applications.

A.5.2 Principal Data Users

The principal users of the modeling results will be PVSC, hydraulically connected PVSC member municipalities, the LTCP engineering consultants supporting PVSC, and other CSO municipalities who elect to utilize the program. The cooperating members of the NJ CSO Group will be paying for the program through reimbursement to PVSC for their proportionate share of implementation, and therefore own the data generated, and may use the data to satisfy certain NJPDES permit requirements related to the requirements of their NJPDES Permits. **Table 1** defines the list of primary model users.

Secondary users of the data, such as the New Jersey Department of Environmental Protection (NJDEP), are responsible for evaluating the data using quality criteria appropriate for their use and/or decision making process.

A.5.3 Decision Makers

PVSC has decision-making authority for the development and application of the PWQM. The Program Manager for PVSC is ultimately responsible for all technical, financial, and resource-related elements of the Program, and is the main contact for interagency communications. Any changes made to the program as outlined in this QAPP will be reported in writing for signatory approval and amendments to the QAPP will be submitted as necessary.

Table 1 – List of Primary Model Users

Central Sewage Treatment Facility	Hydraulically Connected CSO Municipalities and Permittees
Passaic Valley Sewage Commission (PVSC)	Paterson City[1]; Newark City[1]; Kearny Town[1]; Harrison Town[1]; East Newark Borough[1]; Bayonne MUA[1]; Jersey City MUA[1]; North Bergen MUA[1]
Bergen County Utility Authority (BCUA)	Village of Ridgefield Park[1] Fort Lee City[1] Hackensack City[1]
Joint Meeting of Essex and Union Counties[1] (JMEUC)	Elizabeth City[1]
North Bergen Municipal Utility Authority (NBMUA)[1] – Woodcliff Plant	North Bergen MUA[1] Guttenberg Town[1]
North Hudson Sewerage Authority (NHSA)-River Road STP	Weehawken Township[2] West New York Town[2] Union City[2]
North Hudson Sewerage Authority (NHSA) –Adams Street STP	Hoboken City[2] Union City[2]
Middlesex County Utilities Authority (MCUA)	Perth Amboy City[1]

[1] Owns CSO Permitted outfalls discharging to modeled receiving waters. [2]Municipality with CSOs within their limits but not a permit holder

A.6 Problem Definition and Background

The NJ CSO Group was originally formed to work cooperatively to fulfill the requirements of the 2004 master general CSO permit~~last CSO General Permit~~. The group was recently expanded to include more permittees that discharge to the tidally connected waterbodies in the NY/NJ Harbor Estuary. Member utilities provide service to multiple municipalities, and the interrelationships are numerous and varied (**Figure 1**). For example:

- The utilities responsible for providing treatment typically do not have permitted CSOs, which are the responsibility of the municipalities;

- The municipalities with permitted CSOs may not be able to reduce their discharges without the treatment utility modifying its treatment and/or conveyance system;

- Certain municipalities own and operate their own combined sewer systems, interceptors, CSO control facilities, and pumping stations, while others do not own their collection systems; and

- Combinations of utilities and municipalities may jointly own force mains, pumping stations, and other appurtenances but remain independently permitted by the State of New Jersey.

Because of these complex interrelationships, the NJ CSO Group elected to have PVSC lead the technical work required for CSO permit compliance, with participating members paying for the program through reimbursement to PVSC for their proportionate share of implementation. Participating members may use the results generated by the execution of the PWQM QAPP for assessing CSO impacts and potential mitigation strategies.

A.7 Project Description

The following QAPPs are being developed to cover different aspects of the LTCP work activities. It should be noted, however, that not all QAPPs are required per NJPDES permits, nor are all permittees required to submit QAPPs for each of these items to be in compliance with their permit.

1. System Characterization, which includes wastewater collection system precipitation monitoring, flow metering, wastewater quality sampling and analysis as well as landside modeling;

2. Baseline Compliance Monitoring, which includes sampling and analysis of the receiving waters; and

3. Pathogen Water Quality Modeling; which includes the computational model of the receiving waters (Not a permit requirement).

The pathogen water quality model (PWQM) is being prepared to facilitate development of CSO LTCPs for all the CSO permittees in the New York-New Jersey Harbor complex. It is not a NJPDES permit requirement but rather is being developed to allow the CSO permittees to (a) supplement Baseline Compliance Monitoring data; and/or (b) employ the Demonstrative Approach to LTCP development, should they choose to do so. The PWQM will be enhanced from a previously calibrated and validated hydrodynamic and water quality model and then will be validated / re-calibrated with data collected under related programs. Data collected based on the System Characterization QAPP and the Baseline Compliance Monitoring QAPP will provide major sources of information in these efforts.

The enhanced, validated model will be used to project bacteria concentrations in the waters of the NY/NJ Harbor complex under existing and anticipated future conditions to demonstrate attainment of applicable water quality standards. The previously developed Harbor Estuary Program (HEP) pathogen model developed by HydroQual (now part of HDR) will be the platform for model refinement. The HEP model consists of two major components - a hydrodynamic module (ECOM) that defines the transport of the estuarine water throughout the Harbor-Bight-Sound complex, and a water quality module (RCA) which tracks the fate of contaminants and by-products (such as bacteria) in the water column. The water quality component of HEP (RCA) has been appropriately modified to track the fate of pathogen bacteria indicators by incorporating sewer system model calculated outputs of CSO and stormwater discharges as inputs, along with boundary tidal, flow, and meteorological conditions to project varying pollutant concentrations spatially, vertically, and temporally. The HEP modeling approach was reviewed by the model evaluation group (MEG) comprised of independent modeling experts assembled in a manner similar to the one proposed in the present QAPP. The update to that model builds on the previous work and updates it to present day water quality modeling standards.

A.8 Quality Objectives and Criteria

Quality objectives and criteria define the types of data, their intended use, and tolerable limits of uncertainty. The goal of the PWQM QAPP is to create a validated tool capable of projecting pathogen water quality conditions in New York- New Jersey Harbor and connected waterbodies based on current and future estimates of CSO and other Pathogen sources in order to evaluate CSO reduction strategies. The tool will be validated by comparison of results with observed data, and relies on inputs that are also based on observed data. Thus, data and model output must both be evaluated for quality.

The model performance criteria reside largely in the experience and judgment of the modeler. The model "goodness of fit" measure may be either qualitative or quantitative. Qualitative measures that will be used in the development of the water quality model include several types of analysis, including:

- Spatial transect plots of model output versus observed data at an instant in time or under time-averaged conditions;

- Graphical time-series plots of observed and predicted data at individual stations using primary data;

- Comparisons between observed and calculated probability distributions from the same time window; and

- Scatter plots of observed versus predicted values in which the deviations of points from a 45-degree straight line give a sense of fit.

The PWQM will be developed such that it can be used to characterize existing conditions, and assess attainment with pathogen water quality standards for varying conditions of CSO controls, and can reasonably replicate observed timing, duration, and magnitude of ambient data. Since some existing and potential pathogen water quality standards are based on a 30-day geometric mean basis, the model should be able to reasonably reproduce data on a geometric mean basis. Quantitative measures for calibration criteria and skill assessment may include:

- The mean error, in this case, defined as the mean difference between observed and predicted geometric means. A mean error of zero is ideal. A positive nonzero value indicates that the model under-predicts observations; a negative value indicates over-prediction of observed data;

- The absolute mean error, in this case, defined as the mean absolute value of the differences between observed and predicted geometric means. Like the mean error, an absolute mean error of zero is ideal, but unlike the mean error, the absolute mean error cannot give a false zero (i.e., when the positive deviations are about equal to the negative deviations); and

- The relative error, in this case, defined as the ratio of the absolute mean error to the geometric mean of the observations, expressed as a percent. A relative error of zero is ideal. Varied timeframes for these "measures-of-fit" or other tests identified during model calibration and validation will be applied as necessary/recommended.

No single statistic is solely relied upon as a measure of performance, but is used instead in tandem with the other statistical measures. These criteria may be applied during model development and if applied will serve as the primary quantitative measures of acceptance criteria for the calibration and verification of the model. During the calibration and validation process, the WQ Modeling Team will work closely with the MEG to develop more project specific measures of model calibration and validation that will be applied.

Observed data is being or will be collected under separate QAPPs that will employ data quality indicators (DQIs), establish the acceptance criteria for each DQI, and identify the QC mechanisms used to assess if the criteria were met. External QAPPs and data reports will be thoroughly reviewed to ensure the companion data meets its established DQI criteria.

A.9 Special Training Needs / Certification

A clear understanding of project objectives and quality criteria is necessary for project personnel to successfully participate in this project. All staff involved in the development of model codes, model input datasets, and model application will have experience in numerical modeling gained through their work on numerous similar projects. It will be the QA Officer's (QAO) responsibility to ensure that personnel are adequately trained and experienced. Guidance will be provided by senior modelers who have extensive experience using the applicable model(s). In addition, guidance documents will be made available to modelers involved in the project. The QAO will ensure strict adherence to the project protocols.

A.10 Documentation and Records

The following documents are anticipated to be generated as a record of the work performed under the present QAPP:

1. A model re-calibration and validation report documenting the changes of the refined model compared to the base Pathogen TMDL model, along with summarization of model skill, parameterization, inputs, and outputs. The ECOM/RCA based model is well-established, and documentation of its validity and applicability in general is publicly available.

2. Technical memoranda summarizing the results of technical reviews, model tests, data quality assessments, and audits.

3. Electronic files of actual inputs and data used for benchmarking of model skill (re-calibration and validation). This includes the model executable file, model input files, and model output files.

All reports, memoranda, and electronic files will be formatted to facilitate third-party review and use, with the primary goals of transparency, memorialization, and replication by parties other than the original modeling team. HDR will maintain the electronic data on its servers and will make it available to all participating members and their consultants. Paper files, back-ups, and electronic storage at HDR are governed by "Information Lifecycle Governance Policy and Procedures."

SECTION B – DATA GENERATION AND ACQUISITION

B.1 Experimental Design

This section provides the general descriptions of (1) the work to be performed to support the development of an improved hydrodynamic and pathogen model, and (2) the procedures that will be used to ensure that the modeling results are scientifically valid and defensible. The major tasks to be performed as part of this effort are as follows:

- Task 1. Grid Refinements
- Task 2. Recalibrate Hydrodynamics
- Task 3. Revise Pollutant (Bacteria) Loadings
- Task 4. Validate Fecal Coliform Calculations
- Task 5. Validate Enterococci Calculations
- Task 6. Validate E. Coli Calculations
- Task 7. Develop Baseline Projection Conditions
- Task 8. Develop Component Responses

Specific tasks for this Work Assignment are described below.

B.2 Methods

The PWQM will use the previously calibrated and validated hydrodynamic model, modify it, and validate the enhanced model with data collected under related programs. The enhanced, validated model will then be used to project bacteria concentrations in the waters of the NY/NJ Harbor complex under existing and anticipated future conditions to demonstrate attainment of applicable water quality standards.

Grid Refinements

The majority of the existing model grid was developed during the 1990s, and comprises the hydrodynamically connected coastal waters from the eastern Long Island Sound to Cape May, NJ and out to the continental shelf. Because it was initially developed to address New York City issues, certain regions of the model grid were simplified in the interest of model run times and data storage. In 2015, HDR made several refinements to the grid, in part to account for the recent harbor deepening, but also for the specific purpose of supporting the NJ CSO Group LTCP development. Specifically:

- Enhancing longitudinal segmentation in the Passaic River and extending the model from Dundee Dam upstream to the Great Falls;
- Adding Overpeck Creek, and the Elizabeth River;
- Enhancing longitudinal segmentation of the Hackensack River and refining the Meadowlands complex;
- Increasing resolution in the Elizabeth River, Newark Bay, Arthur Kill, and Kill Van Kull;
- Enhancing lateral segmentation in the Hudson River to improve near-shore resolution;
- Enhancing lateral segmentation in Newark Bay to account for channel deepening; and
- Modifying bathymetry to account for the Harbor Deepening Project.

Figure 2 attached shows the model grid; **Table 2** summarizes the change in resolution. The ECOM and RCA model components use the same segmentation, with model cells averaging about 500 meters on a side, but as small as 30 meters in the coastal areas of New Jersey. The model contains 10 vertical sigma layers, meaning that all areas of the model will have 10 vertical layers but the depth of the layers will vary depending on the local depth. Available tidal, water temperature, salinity, freshwater flow and meteorological data will be used as model inputs.

Table 2 – Grid Resolution Improvements, 1990 to 2015

Model	Number of Grid Cells	Smallest Grid Cell Size (m^2)	Largest Grid Cell Size (km^2)	Average Grid Cell Size (km^2)
1990s Grid	1,654	39,280	1,520	40
2015 Grid	3,953	940	1,520	0.25~~20~~
Change	+139%	-98%	0%	~~-50%~~-99%

Recalibrate Hydrodynamics

The ECOM hydrodynamic model outputs for tide elevation, current velocity, salinity, and temperature will be compared with available data (**Table 3**) for the calibration period to determine whether deviations are within an acceptable level, based on best professional judgment and limited statistical comparisons as defined by the MEG. Hydrodynamic information will then be passed forward to the pathogen water quality model on an hourly averaged basis. The model requires external flows and loads as inputs, among others.

Revise CSO Pathogen Pollutant (Bacteria) Loadings

The pollutant loadings to the revised surface water model will be estimated based on several sources. Outputs from existing landside models (SWMM, InfoWorks, RAINMAN) will provide estimates of CSO and stormwater flow and the relative fraction of sanitary and stormwater flow in CSO. Bacteria concentrations will be measured during Landside Characterization on a limited basis (i.e., not at every outfall) or will come from published literature, and land use data will allow those concentrations to be assumed to apply in watersheds of similar land use properties.

Table 3 – Observed Data Used in Hydrodynamic Recalibration

Output	Data Set
Tide Elevation (ft)	USGS – Hackensack River at Hackensack; Passaic River at PVSC NOAA – Sandy Hook, NJ; Bayonne Bridge; Bergen Point West; Verrazano Bridge; The Battery
Current Speed (mm/s) and Direction	NOAA predictions Passaic River Superfund 2009-2010 ADCP data
Salinity (ppt) and Temperature (^{o}C)	NJHDG – 2016 Annual Survey PVSC – 2016 LTCP Baseline Compliance Monitoring and Intensive Sampling Events NYCDEP – 2016 Harbor Survey

There is considerable variability in CSO pollutant loadings: laboratory analytical methods for bacteria concentrations are such that data is known only to an order of magnitude precision and is often reported on log scale graphs. Individual measurements of bacteria concentrations in sanitary sewage, CSO and stormwater typically differ by orders of magnitude as well. Add to this spatial variability from outfall to outfall and it is evident that the data volume necessary to generate a predictive tool approaches practical limits.

To overcome the inherent data limitations and uncertainty in bacteria loadings, three basic approaches to estimate CSO pollutant load were considered:

1. The Mass Balance Approach, in which constant sanitary and stormwater concentrations are applied to the time-varying fractions of sanitary and stormwater flow rates generated by the CSO landside models;

2. The Monte Carlo Approach, where CSO concentrations are generated randomly from a probability distribution based on observed data; and

3. The Hybrid Approach, which combines these two approaches by applying the Monte Carlo Approach to each of the stormwater and sanitary fractions, then following the Mass Balance Approach with the resulting CSO concentrations.

Each of these has its benefits and challenges. The Mass Balance Approach was selected as the preferred method as it is simple, consistent, and predictive, and was used in previous modeling efforts for the NY/NJ Harbor Pathogen TMDL where it underwent considerable peer review. The Mass Balance Approach will be used to establish CSO pollutant loadings but will be verified and its adequacy evaluated by comparing calculated CSO pathogen concentration estimates to data collected under the System Characterization QAPPs, and the approach may be modified if needed to improve model verisimilitude.

Pollutant loadings will be calculated using modeling results from both NJ municipalities and the City of New York. Historically, the New York City Department of Environmental Protection (NYCDEP) developed pollutant loadings from their CSO service areas during facility planning, and NYCDEP continues to maintain and improve a set of InfoWorks models for all combined service areas of the City. NYCDEP has indicated that they will provide model outputs of CSO and stormwater loadings capable of being used in the RCA model. Similarly, New Jersey municipalities have been developing site-specific landside modeling tools for their particular municipalities. All of the New Jersey CSO communities have developed either a SWMM version model or an InfoWorks model of their CSO collection systems. Each of these New Jersey models will receive some level of recalibration/validation using data to be collected under the System Characterization QAPPs. These models will be used to the extent available, and the models for municipalities hydraulically connected to PVSC will be incorporated into PVSC's InfoWorks model as described in the companion QAPP for System Characterization and Landside Modeling.

Bacteria concentrations will be assigned based on data collected on sanitary flows collected during dry weather under the System Characterization and Landside Modeling QAPP. ~~Stormwater concentrations will be assigned based on wet weather stormwater measurements~~

~~under that QAPP as well. However, not all stormwater areas will be measured. Concentrations will therefore be applied to other drainage areas based on the NJDEP 2007 Land use/Land Cover Update of 2010. This GIS data layer is available from NJDEP and relies on the Modified Anderson System for land use classification. Because there are over 80 specific codes and the PVSC service area is highly urbanized, the classification system will be modified to reduce the overall number of unique land use categories and better represent the variability of land use in the service area. The initial categorization expected to achieve this is as follows:~~

- ~~All areas defined as Wetlands, Forest, Agriculture, and Barren Land will be considered a single type known as "Open Space"~~
- ~~Areas defined simply as Urban will be further classified into "High Density Residential," "Low Density Residential", "Commercial," and "Industrial"~~

~~A single runoff bacteria concentration will be assigned to each area based on the data collected from areas of similar categorization.~~

Revise Tributary Pathogen Pollutant (Bacteria) Loadings

An additional source of loadings to the PWQM waters is direct inflow of pathogens from tributaries to the modeled receiving waters. These loadings will be estimated through a number of methods. The primary approach will be to use USGS gauged flows combined with measurements of pathogens developed as described in the Baseline Compliance Monitoring Program QAPP. A secondary approach will be to use measured flow/drainage area ratios assigned to ungauged tributaries based on local adjacent USGS gauged streams.

Revise Stormwater Pathogen Pollutant (Bacteria) Loadings

All areas tributary to the PWQM waters that remain after accounting for CSO drainage areas and gauged tributary streams will be considered as sources of ungauged stormwater. This would include both municipal separate storm sewer systems (MS-4) urban/suburban stormwater as well as runoff from industrial areas, transportation corridors, and other areas that drain directly to the PWQM waters. Runoff flows from these areas will be provided in accordance with ~~based on~~ calculations specified in the Landside Modeling QAPP~~developed from watershed models that will be developed as part of the water quality modeling work efforts~~. The runoff flows will be combined with pathogen concentrations that will be developed based on the GIS land use assignments within those areas and pathogen concentrations assigned to the land uses based on measurements and/or literature values.

Open Ocean Boundary Conditions: The open ocean is not expected to be an important source of pathogens, but the model requires boundary conditions to be specified. A small, non-zero concentration of pathogens will be assigned at the open ocean boundary.

Recalibrate/Validate Fecal Coliform Calculations

Previous calibration of the HEP PATH TMDL model was based on conditions from the mid-to-late 1980s, and then was recalibrated to data from 2002 and 2004. However, substantial environmental improvements have occurred since that time and are likely to continue to occur: The NYCDEP Harbor Survey Data shows dramatic improvement in bacteria levels, particularly in the Hudson River, over the past 10 years. In addition, dredging of portions of the New York-New Jersey Harbor has continued changing the circulation patterns within sections, particularly Newark Bay. –Therefore, a recalibration of the fecal coliform bacteria calculations will be performed using primary data collected under the Baseline Compliance Monitoring Program QAPP and~~,~~ the NJHDG Annual Program~~, and the NYCDEP Harbor Survey~~. The model will be considered recalibrated when the comparison of results and data meets the standard of best professional judgment and any quantitative statistical measures recommended by the MEG. The recalibration analysis will be followed by a validation of the model using data from a different period, primarily NJHDG data but potentially other sources identified once the validation period is chosen. An estimate of level of validity will be made so that any projections provided will include a statement on model uncertainty.

Recalibrate/Validate Enterococci Calculations

Recalibration/Validation of enterococci calculations will follow a similar protocol to fecal coliform. The enterococci kinetics rely on a slightly different decay coefficient from the fecal coliform, and so must be recalibrated/validated separately.

Calibrate/Validate E. Coli Calculations

Calibration/Validation of E. coli calculations will follow a similar protocol to fecal coliform. The E. coli kinetics rely on a slightly different decay coefficient from the fecal coliform model, and so must be calibrated/validated separately. The E. coli water quality criteria only apply to the freshwater sections of the model domain, so the calibration/validation will only focus on these areas.

Develop Baseline Projection Conditions

Once the model is calibrated, the model will be used to evaluate the sources of bacteria and their impact on water quality. These results will dictate the allowable loads to the Harbor to maintain water quality standards. The first step in the development of the allowable loads is to develop Baseline Projection Conditions that would include meteorological and hydrodynamic conditions for projection scenarios. Baseline Projection Conditions will be defined in close consultation with PVSC, NJDEP, and other stakeholders as appropriate. The specific constraints that must be defined for Baseline Projection Conditions will allow differences in projections to be assessed. **Table 4** summarizes the parameters that must be established to define Baseline Projection Conditions.

Table 4 – Baseline Parameters and Influences

Parameter	Current Influences	Potential Future Influences
Simulation Duration	Modeling decision, e.g., 1 year, multiple years, "typical year"	Same
Wastewater Treatment Plant Dry Weather (Sanitary) Flow	Population water conservation I&I	Population growth Ongoing O&M
Wastewater Treatment Plant Wet Weather Treatment Capacity	Facility performance Interceptor sediment levels Interceptor and pumping capacity	Ongoing O&M Conveyance enhancements
Receiving Water Level	Tides Riverine flow Runoff	Sea level rise Climate change
Stormwater runoff and CSO discharges	Precipitation Spatial Distribution Green infrastructure	Land use changes Planned infrastructure Climate change
Other pathogen sources	DWO / SSO / I&I / failing septics / exfiltration / illicit connections Upstream and downstream sources	Compliance vs. non-compliance River/Tributary conditions Flows

Two significant sources of pathogens in NY/NJ Harbor are CSO and stormwater discharges, which are driven by rainfall. These discharges, particularly CSOs, are a function of rainfall volume, duration, and intensity. Since the discharge of bacteria is a function of several rainfall parameters it is not intuitively obvious which years of historical rainfall are the most critical or which year is the most representative of a desired condition.

Ideally, it would be beneficial to simulate a long-term record of about 30+ years. In this way, pathogen indicator responses would be representative of all historical summer rainfall scenarios; these responses would include dry, average, and wet summer conditions. However, assembling

30+ years of Harbor hydrodynamics and simulating water quality responses for 30+ years is time-consuming and expensive, especially in light of the fact that the CSO Policy and subsequent planning guidance indicates that "typical conditions" should be used when developing Long Term Control Plans. Previous efforts accepted by NJDEP include using the rainfall record at JFK in 1988, considered to be representative of an "average" yearly rainfall condition. In addition, under HEP a critical "wet" condition was represented by 2003. More recently NYCDEP revisited JFK 1988 using more recent rainfall records and established JFK 2008 as most representative of New York City for the recent past and JFK 2005 as typical of the most likely future conditions of the 2050s. Projection conditions have not yet been established for the NJ CSO Group study area, but will be based on detailed analysis of historical rainfall records from available New Jersey gages.

After the hydrodynamic Baseline Projection Conditions are established and the hydrodynamic model is executed, the water quality model, which tracks the decay of pathogens, would be executed for the Baseline Projection period. Pathogen input loads to the PWQM would be generated from the landside sewer system models.

These selected design conditions will be developed jointly with the cooperation PVSC, NJ CSO Group and NJDEP. Projected loads for fecal coliform, enterococci, and E. coli will be developed for the selected baseline condition. Results of the simulation will be graphically displayed as a series of probability distributions at key locations of the Harbor (beaches, shellfish areas, others). These can be directly compared to pathogen standards. An assessment will also be made at key locations regarding the percent of time pathogen are in compliance with standards

Develop Component Responses

Components are defined as the various sources of pollutants to the receiving water. A component analysis quantifies the impacts of the source categories (both geographical and type) to assess which are most influential in a particular time or location. This phase is necessary to establish the level of load control to target during LTCP development. The PWQM will be applied to simulate component analyses to assess the impacts of various source categories and jurisdictional areas on water quality. In addition, four source categories will be evaluated: CSO, stormwater- and direct drainage, boundary sources, and New York City (CSO, stormwater and direct drainage). The runoff loads from each jurisdictional area must be segregated and quantified by the three source categories in preparation for the component simulations. The design conditions for this task will be based on the results of the Development of Baseline Projection Conditions task and recommendations from the MEG.

Based on the results of previous tasks, the information needed for preliminary development of load responses must be put in a usable format, such as a graphical plot of concentration versus location, simple spreadsheet or text file. The final alternatives will be simulated using the PWQM and will be included in the LTCP submitted by PVSC and as appropriate in LTCPs submitted by other CSO permittees.

B.3 Quality Assurance and Quality Control

HDR employs an internal Quality Management System (QMS) based on the fundamental principles and guidelines set forth by ISO 9001:2008 series of international standards for quality. The HDR QMS consists of four principal components:

1. Documentation that establishes procedures and best practices designed to consistently meet applicable standards of care. These include QMS best practices, administrative and QA/QC procedures, and standards that define the structure, requirements, and actions necessary to control, record, and measure project quality activities.

2. A Quality Steering Committee comprised of quality officers and project delivery representatives within HDR, who maintain QMS documentation and review and revise quality processes.

3. Explicitly defined QMS implementation responsibilities at each level within the firm hierarchy.

4. An Internal Audit Program conducted to verify that the QMS is being effectively implemented and maintained, and to ensure corrective action is taken to address opportunities for improvement or instances of non-conformity.

QA/QC will be conducted and documented in accordance with the HDR QMS. The specific steps required for the Water Quality Modeling Program include:

- The *Zero Percent Review* at the outset, when HDR leadership and QMS staff will review the project with the HDR Project Manager to ensure that proposed staff are available, appropriately designated and qualified to work on the project;

- Early in the process a *Project Approach and Resource Review (PARR)* is performed by HDR leadership and QMS staff to independently verify that appropriate solutions are being considered to meet project goals, an appropriate technical approach is being implemented, and appropriate staff is being utilized;

- Every deliverable will undergo *Deliverable QC* to verify and document that project deliverables and supporting work products are complete, understandable, conform to applicable and reasonable standards relative to their intended purpose, and meet PVSC and HDR requirements. This includes a *Quality Review Check*, which determines when checking can begin and verifies that checking has been completed;

- *Project Reviews* at financial or production milestones to review project status and identify any areas where actions may be required to improve project performance, including technical issues on the project and staffing assignments; and

- *Closeout Review* at the end of the project to verify and document obligations are completed and final project records are prepared.

The HDR Project Manager will identify the specific QC Reviewers based on the required qualifications and will check deliverables generated by others, but will not serve as the QC Reviewer. QC reviews will be conducted by experienced personnel who are not otherwise involved in producing the documents or directly involved in providing the services, but are qualified in the process and discipline(s) required. Independence from the work being reviewed ensures an impartial assessment, and allows the reviewer to consider project objectives as well as technical details. QC results that fail the appropriate quality control criteria will be corrected prior to release.

B.4 Data Management

All active project files (electronic and paper) will be filed in accordance with the QMS Project File Management protocols and HDR's Internal Lifecycle Guidance Policy. At the conclusion of the project, the HDR Project Manager will consolidate hard-copy files, review for appropriateness of retention as final records, convert to electronic media (where possible). Documents and records that are an integral part of work activities, including master files, QC review documents, and completed QC review forms, will be verified, and duplicate, draft, and obsolete documents will be eliminated.

Electronic project records stored in the Final Records folder will systematically be transferred to the records repository when the HDR Project Manager confirms final close-out status. Any project files in a medium that cannot be stored electronically will be documented, assigned a retention schedule, and stored in accordance with department off-site storage processes. The records inventory will be prepared and maintained by HDR's Quality & Records Coordinator.

SECTION C – ASSESSMENT AND OVERSIGHT

C.1 Assessments and Response Actions

As development of the model progresses, assessments will be performed periodically to ensure that activities are being conducted as planned. The calibrated, validated model requires each step to be performed and completed in sequence. For the purpose developing the PWQM, the data that will be used in this modeling effort will have been collected under separate QAPPs or under detailed work plans providing document quality procedures.

Analysis and interpretation of compiled information will employ a rational engineering framework to assure compliance with accepted engineering practices and past observance of normal performance. Only data meeting quality criteria established for the project will be accepted for analysis.

Engineering analysis, program results and the final work product will undergo detailed technical review to assure that products are accurate and complete, fall within guidelines for accepted engineering practices and meet the project objectives.

Continuing review by oversight entities, such as the HDR Water Quality Modeling Task Leader, the HDR Quality Assurance Officer, the MEG and PVSC and PVSC's LTCP Consultants, will ensure that the objectives of the study are achieved.

A summary of these assessments will be included in the modeling report and in a modeling journal. Such reporting will describe how and to whom the results of the assessments were presented and any resolutions taken. It will provide forms or checklists used to document assessment and response/corrective action activities in an appendix/attachment. **Table 5** provides typical assessments and response actions used in model development.

C.2 Model Application

Model Parameterization (Calibration)

Model calibration is the process of adjusting model inputs within acceptable limits until the resulting predictions provide favorable correlation with observed numerical data independently derived from field observations in the environment. Commonly, calibration begins with the best estimates for model inputs based on field measurements and laboratory studies, based on literature values, based on previous modeling experience and based on subsequent data analyses. Results from initial simulations are then compared to observed data and used to guide changes to the values of the model input parameters.

Table 5 – Assessments and Response Actions

Task	Inputs	Outputs	Assessment(s)	Response(s)
Grid Refinements	Bathymetry Roughness	Updated grid	Stability, run time, gross circulation pattern	Adjust grid
Recalibrate Hydro-dynamics	Head and stage Elevations, tributary riverine inflows, outfall discharges, meteorology	Calibrated hydrodynamic model	Data/model comparison for head and stage elevations, velocity (timing, magnitude, and direction), salinity and temperature	Adjust forcing functions, bottom roughness. Verify meteorology and water quality data.
Revise CSO Bacteria Loadings	CSO quality and quantity	CSO pollutant loadings	Mass balance/CSO data comparison for overflows	Evaluate alternate approaches to calculation of CSO overflows.
Revise Bacteria Loadings	Landside inputs, Upstream points, Tributary, local runoff and distributed inflows	Pollutant loadings	Overall evaluation of dry and wet weather receiving water pathogens versus model results from known sources	Potentially add unknown dry weather pathogen inputs in affected reaches.
Validate Bacteria Calculations	Bacteria loadings, model kinetic die-off coefficients	Validated fecal coliform, enterococci, and E. coli calculations	Comparisons of model/data water column concentrations; distribution of wet and dry weather model/data	Re-assessment of bacteria loadings; refinement of die-off coefficients
Develop Baseline Projection Conditions	Rainfall, winds, tides, treatment plant capacity, etc.	Baseline projection conditions	Compile model inputs needed to conduct future condition assessments	Work with NJDEP to define future conditions for model projections.
Develop component responses	Pathogen pollutant sources	Load-WQ response relationships	Establish the effects of individual sources on receiving water pathogen concentrations.	Determine contributions to observed pathogen quality

Updating model code is not anticipated so at this point the focus of the calibration will be on the hydrodynamic circulation and the pathogen concentrations. On the NJ side, data were limited and virtually no wet weather data existed so that portion of the model (which had been used for the pathogen TMDL) requires rigorous examination. Model/data comparisons will include visual inspection early in the process and then move to more quantitative measures of "goodness of fit" including statistical measures as recommended by the MEG. During the assessments the goal will to be conservative so that the PWQM calculation will err toward overestimation of observed pathogen concentrations.

HDR has performed this type of model calibration within the New York-New Jersey Harbor environs multiple times and believes that few adjustments will be required to any elements of the hydrodynamic portion of the model. The focus of most of the effort is anticipated to be as follows.

- Hydrodynamic model – Generally, once the grid is properly designed, it should be capable of simulating water movements, salinity and temperature. However, calibration efforts will focus on further enhancing the grid to properly resolve local currents and confirming that all forcing functions are properly resolved including fresh water tributary and runoff flows, wind speed and direction, and large scale open boundary tides and currents. Rather than attempting to model riverine systems, the upstream boundaries of the model domain are set to USGS gage locations so that flow data from these gages can be used as inputs to the model.

- Pathogen model – The pathogen model calibration is anticipated to focus on two major items. The first being the proper development of pathogen loadings. This will start as noted above with the CSO, stormwater, and tributary loadings. As noted, the mass balance approach will be employed to calculate CSO pathogen loadings. Should this approach not reproduce the variability of the observations, then the calibration will shift to an alternate method of load development. The next issue with respect to pathogen modeling is expected to be ~~illicit connections and/or undocumented dry weather inflows of pathogens~~unidentified pathogen loads. Both factual and anecdotal information exists that indicates portions of the PWQM waters are influenced by local sources of dry weather bacteria inflows. Another area where adjustments may be made in the PWQM will be the fecal coliform, enterococci, and E. coli decay or die-off coefficients. There is a long history documenting the decay coefficients that will be used to start the assessment showing that they are a function of salinity and temperature. The literature also shows that factors not previously considered such as solar radiation also impact the die-off rate and settling of solids can impact the mass balance of bacteria in the water column. Therefore there is the possibility that local adjustments will need to be made to account for additional die off associated with things like the depth of light penetration and/or localized solids settling in quiescent areas. HDR will initiate the process of making such adjustments using literature relationships. Once reasonable die-off rates are developed, model sensitivity analyses will be performed by increasing and decreasing the rates by +/- 50% to assess how sensitive the model responses are to the final die-off values.

Model Corroboration (Validation and Simulation)

Model validation is the process of comparing the output predictions from a calibrated model against observed numerical data independently derived from field observations in the environment and evaluating the degree of verisimilitude. The validation run will span a different time window than the one used for calibration. In principle no adjustments are made to model parameters in the validation phase: either the model is in agreement to an acceptable degree or not. In practice however, the results may indicate very minor adjustments or reveal data anomalies that were not detected during calibration. The validation uncertainty and soundness will be based on the same qualitative and quantitative practices used for calibration.

Reconciliation with User Requirements

Data anomalies are always a possibility when performing these types of assessments. One anomaly that can often be found in pathogen modeling is false positive fecal coliform measurements. These would represent fecal coliform bacteria laboratory results that pass all internal field and lab QC reviews but are the result of the growth of non-fecal bacteria on the incubated media. To ascertain if this is occurring in any local waters, HDR will examine the ratio of fecal coliform bacteria to enterococci (FC/Entero ratio) for all samples in all waterways. Although there is no one single FC/Entero that can be associated with this type of sampling, typical ranges of this ratio are from a low of 0.5 to about 10. Any ratio in that range would be considered typical. Local waters have often shown that ratios can average 100 or more. Should this be the case, those fecal measurements will be flagged as abnormal and removed from the model calibration/validation analyses. Regardless of what data is used, all data collected will be included in the database and unused data will be flagged as such.

C.3 Reports to Management

Thorough documentation of all modeling activities is necessary for the interpretation of study results. HDR will prepare monthly progress reports, a draft final report, a final report and other deliverables, which will be distributed to project participants. The final report will contain the following information:

- Available data used as model inputs and for calibration/validation

- Model revision and developments
- Model application
- Calibration
- Validation
- Baseline Projection Conditions
- Component Analyses

Since there is a long history of model development and testing, the report will also include a comprehensive list of references to previous reports and publications. The draft outline of the modeling report is shown below:

I. Introduction
   a. Background
   b. Purpose and Objectives
   c. Physical Setting

II. Observational Data Supporting Model
   a. Quality and Quantity
   b. Achievement of Acceptance Criteria
   c. References
   d. Excluded Data

III. Model Description
   a. Model Selection
   b. Successful Applications

IV. Model Configuration
   a. Spatial and Temporal Resolution
   b. Grid, Network Design, Delineation
   c. Application of Sub-models
   d. Model Inflows, Loads, and Forcing Functions
   e. Key Assumptions
   f. Changes and Verification of Changes Made in Code

V. Calibration and Validation
   a. Objectives, Activities and Methods

b. Parameter Values and Sources, Rationale
c. Calibration Targets, Inputs, Outputs, Measures of Performance
d. Calibration Results
e. Validation Results

VI. Projections
a. Output and Interpretation
b. Summary of Assessments and Response Actions
c. Soundness of Calibration, Validation and Projections
d. Review of Initial Assumptions and Model Suitability Evaluation

VII. Performance against Calibration, Validation, Sensitivity and Uncertainty Criteria

VIII. Pre- and Post-Processing Software Development

IX. Deviations from the QAPP Including a List of Non-Applicable Reporting Elements with Explanations.

X. Conclusions and Recommendations

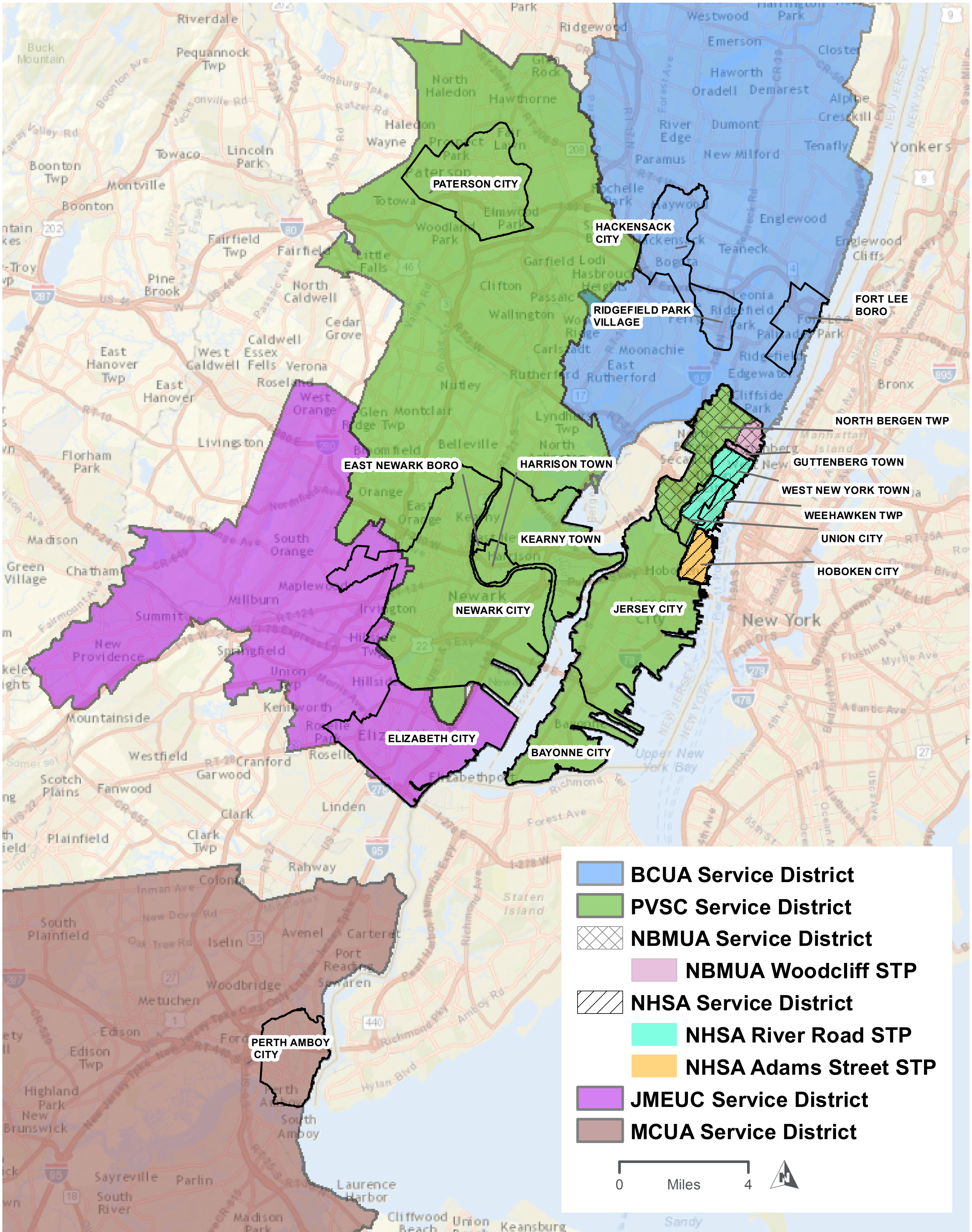
XI. References and Appendices

REFERENCES

EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5, EPA/240/B-01/003, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, March 2001

HDR, Information Lifecycle Governance Policy and Procedures

ATTACHMENTS

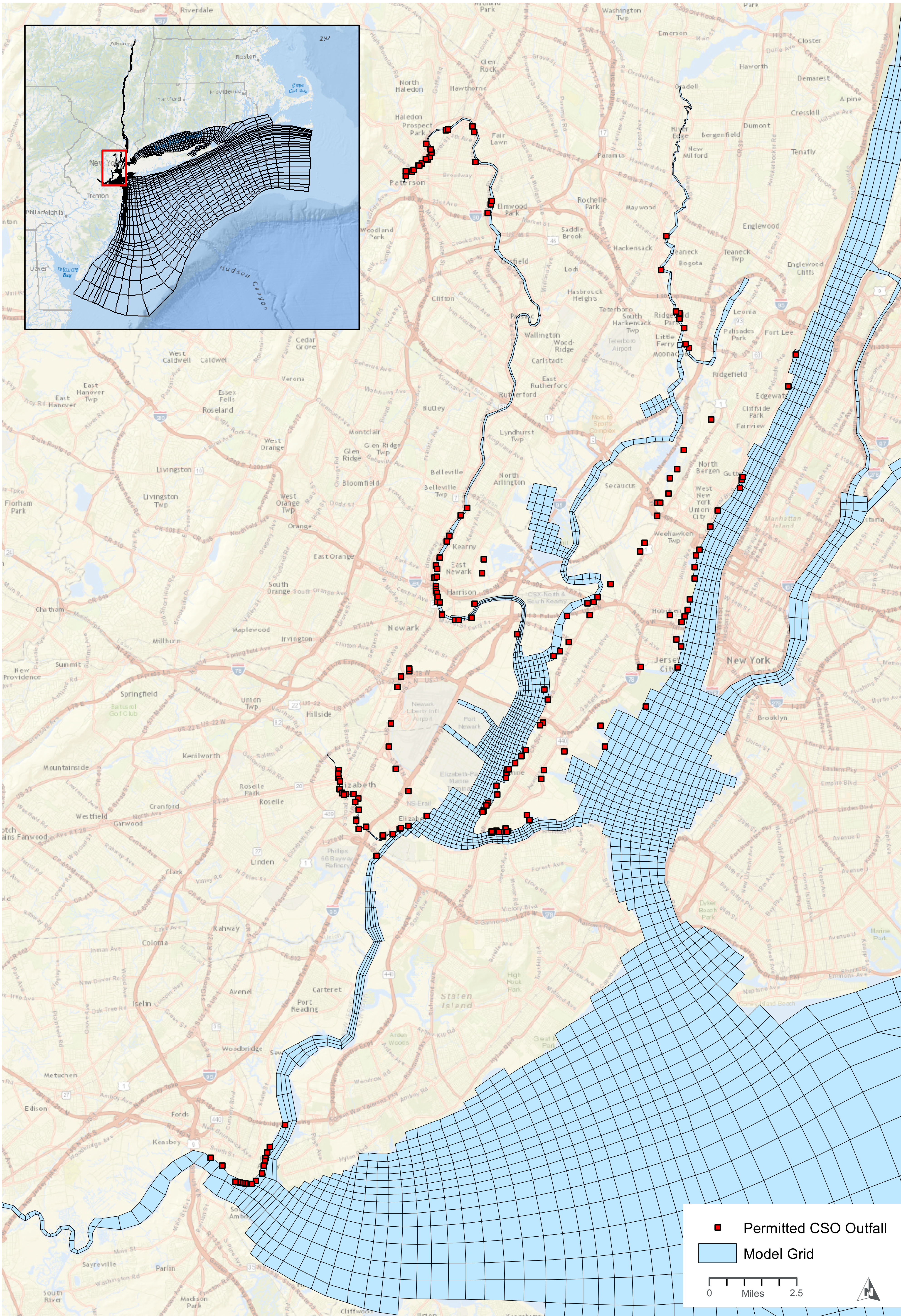


HDR

PATHOGEN WATER QUALITY MODELING QAPP

PARTICIPATING NJ CSO GROUP MEMBERS AND ASSOCIATED CENTRAL SEWAGE TREATMENT FACILITIES

FIGURE 1



PATHOGEN WATER QUALITY MODELING QAPP
MODEL GRID
FIGURE 2

State of New Jersey

CHRIS CHRISTIE
Governor

KIM GUADAGNO
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
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Bureau of Surface Water Permitting
P.O. Box 420 – 401 E State St
Trenton, NJ 08625-0420
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BOB MARTIN
Commissioner

November 14, 2016

Bridget M. McKenna, Chief Operating Officer
Passaic Valley Sewerage Commission (PVSC)
600 Wilson Avenue
Newark, NJ 07105

Re: Pathogen Water Quality Model (PWQM) Quality Assurance Project Plan (QAPP)
NJCSO Group

Dear Ms. McKenna:

The Division of Water Quality's (DWQ) Bureau of Surface Water Permitting (BSWP) Combined Sewer Overflow Program has received the Pathogen Water Quality Model (PWQM) Quality Assurance Project Plan (QAPP) dated May 19, 2016. This QAPP was prepared on behalf of the NJ CSO Group Permittees by Passaic Valley Sewerage Commission (PVSC).

The purpose of the PWQM QAPP is to facilitate development of CSO LTCPs for all the CSO permittees in the New York-New Jersey Harbor complex. It is not a NJPDES permit requirement but rather is being developed to allow the CSO permittees to supplement Baseline Compliance Monitoring data and/or employ the Demonstrative Approach (Part IV.G.4) to LTCP development. The PWQM will be enhanced from a previously calibrated and validated hydrodynamic and water quality model and then will be validated / re-calibrated with data collected under related programs. The enhanced, validated model will be used to project bacteria concentration in the waters of the NY/NJ Harbor complex under existing and anticipated future conditions to assess against applicable water quality standards.

Since the enhanced, validated model will be used to assess water quality of the NY/NJ Harbor complex and because the NJDEP's Bureau of Environmental Analysis, Restoration and Standards (BEARS) role includes responsibilities for conducting and coordinating water quality assessments of all waters of the State, this letter is issued in coordination with BEARS. NJDEP's comments are as follows:

Comment 1, Section A.1, pages 4, 7 and 9 – Please replace the signature line for Debra Waller, Office of Quality Assurance with Biswarup Guha of the Bureau of Environmental Analysis, Restoration and Standards. A signature by NJDEP's Office of Quality Assurance is not required since this PWQM QAPP does not include new water quality sampling. In addition, please replace Marc Ferko with Biswarup Guha on the Program Contact Information on page 9.

Comment 2, Section A.5.1, page 17 and 18, Model Evaluation Group (MEG) –A BEARS' representative should be involved during future Model Evaluation Group (MEG) discussions. MEG should address the question if the calibrated model will be technically defensible for the Department to rely upon it for regulatory decision making. Confirmation/vetting from MEG would help NJDEP in the event that the model is challenged in the future. This could be spelled out in the leading paragraph of this section.

Comment 3, Section A.6, page 19 – Clarify the "last CSO general permit" with the date "2004 master general CSO permit."

Comment 4, Section A.8, page 22 – Please delete the following sentence: "Since existing and potential pathogen water quality standards are based on a 30-day geometric mean basis, the model should be able to reasonably reproduce data on a geometric mean basis." Note that all waters within the model domain are not downgraded. Also, NJDEP is in the process of updating the recreational criteria that introduces a new measure, statistical threshold value (STV), in addition to the existing geometric mean. It is recognized that the model may not be able to reproduce the exact calibration data; however, the model should be able to reasonably reproduce the timings, duration and magnitudes of the ambient data. For example, if data shows very high concentrations in a week and the model fails to show any high concentrations, that scenario would not be acceptable during calibration review.

Comment 5, Section A.8, page 22 - Where relative error is discussed in the third bullet, it is recommended that the following be added: "Varied timeframes for these "measures-of-fit" or other tests identified during model calibration and validation will be applied as necessary/recommended."

Comment 6, Section A.10, page 23 - Section A.10 describes documentation and records. Please confirm that the model executables and the input and output files will be provided to the Department for review of model calibration and validation.

Comment 7, Section B.2, page 25, Grid refinements - Please provide the citations for each of the bulleted refinements for future reference. There should be documentation of the references being used for the grid refinements. For example, is NOAA bathymetry being used or is information from the Army Corps being used?

Comment 8, Section B.2, page 28 - Land Use/Land Cover data from 2012 should be used instead of 2007. Alternatively, provide a table showing the cross-walk with the percentages to substantiate the claim that 2007 and 2012 land uses are similar. If so, a comparison should be included in the QAPP and it should be stated why use of 2007 land use would not affect the model calibration.

Comment 9, Section B.2, page 28 - When categorizing land use areas, Agriculture, Wetlands and Forest should not be linked with Open Space as the bacterial load from Agricultural could be very different than Forest and Wetlands (even if no livestock, there may be Geese that frequent field crops). Barren land, particularly in urban areas, is more appropriately categorized in the urban category. If these changes have any effect on the inputs developed, such findings should be stated in the QAPP.

Comment 10, Section B.2., page 29 Clarify the sentence: "Runoff flows from these areas will be based on calculations developed from watershed models that will be developed as part of the water quality modeling work efforts." There should be a map indicating which portions of the watershed are modeled by which model, and by whom. It could also work if other documents (landside QAPPs) are referenced.

Comment 11, Section B.2., page 29 – Please indicate the universe of stations that will be considered for calibration and validation. Perhaps this can be resolved through a reference to the Compliance Monitoring Program QAPP.

Comment 12, Table 4, page 31 - How are “sea level rise, climate change” impacts incorporated? It should be clarified what PVSC implies with such assessment. Will it be only an incorporation of the temperature change, or will sea level rise will be addressed outside the PWQM?

Comment 13, Section B.2., page 31 - After the model is vetted by the MEG, at the time of developing Baseline and Projection Conditions, wet, dry and average years shall be determined using analysis of rainfall records from NJ sites and shall be coordinated with the Department and New York City DEP in order to maintain consistency throughout the model domain. Use of the gage at JFK is appropriate for the LTCPs that NYC is developing; however, the rainfall patterns in NJ may be different. Please add language in this section to confirm the same.

Comment 14, Table 5, page 35 - Add a “Source” Column that would detail the source of the inputs. Future changes should be tracked/organized via a similar table. The existing table does not include the basis of the inputs.

Comment 15, page 36, Hydrodynamic model - Monitoring and modeling extends to the non-tidal Passaic River, please confirm that this effort will assess factors (such as diversions and releases) if necessary. –

Comment 16, page 36, Pathogen model – Regarding the following statement concerning calibration of the pathogen model:

> “The next issue with respect to pathogen modeling is expected to be illicit connections and/or undocumented dry weather inflows of pathogens. Both factual and anecdotal information exists that indicates portions of the PWQM waters are influenced by local sources of dry weather bacteria inflows.”

Additional detail should be provided as to how these factors will be addressed in the model as well as any alternative assessment methods. Where are these areas and is more monitoring needed in these spots? A statement could be added that the QAPP will be updated with a map showing locations of such occurrences, after analyzing the dry weather monitoring data or during the calibration process. Such information could be useful during the LTCP development.

Comment 17, Section C.2., page 37, Reconciliation with User Requirements – Regarding the following statement on page 37:

> “Should this be the case, those fecal measurements will be flagged as abnormal and removed from the model calibration/validation analyses.”

Please confirm that any data that is QA’d and determined good during the lab QA process will be flagged and reported in the database even if not used for calibration.

Please provide a revised work plan addressing the issues discussed above within 60 days from the date of this letter.

Thank you for your continued cooperation. Feel free to contact me at (609) 292-4860 or at susan.rosenwinkel@dep.nj.gov if you have any questions regarding this letter.

Sincerely,

Susan Rosenwinkel
Section Chief
Bureau of Surface Water Permitting

C: Biswarup Guha, BEARS
Helen Pang, BEARS
Frank Klapinski, Jr., BEARS
Kim Cenno, BEARS
Joe Mannick, Bureau of Surface Water Permitting
Marzooq Alebus, Bureau of Surface Water Permitting
Dwayne Kobesky, Bureau of Surface Water Permitting